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A RECORD OF POST-GLACIAL CLIMATE IN NORTHERN OHIO.*†

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OBJECT AND CHARACTER OF THE INVESTIGATION.

This paper reports the probable course of post-glacial forest succession in northern Ohio, as indicated by a study of fossil pollen deposited in the Bucyrus Bog. The object of the study has been to trace in greater detail than has yet been possible the course of climatic change since the end of the Wisconsin glaciation.

The principle employed is one which has been used in numerous European studies since 1915. It consists of a tabulation of the percentages of pollen grains of each species found in successive levels of bog deposits, and deduction of the prevailing forest composition at each level from this data. From the forest composition conclusions as to climate are drawn.

As in all stratigraphic work, certain assumptions are involved, and numerous sources of error can be pointed out. These matters have been discussed at length and tested by workers cited in a previous paper (1). For the purpose of the present paper it is perhaps sufficient to note the following points: (a) no successful impeachment of the method has appeared, although there have been several attempted (b) pragmatically, the method appears to work, and to give results which agree with those obtained otherwise (c) the method requires a clean and accurate technique, a knowledge of pollen, and an understanding of what constitutes a climatically significant fluctuation in the tabulated results.

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LOCATION AND CHARACTER OF THE BUCYRUS BOG.

This bog of about forty acres I have named from the nearest city. It was evidently overlooked by Dachknowski (2) in his survey of Ohio peat deposits. It lies two miles due east of Bucyrus, Ohio, on the North Robinson Road, fourteen miles south of the 41st parallel, and three miles east of the 83rd meridian. The glacial physiography of this region is mapped and described by Leverett (3), and the natural vegetation by the writer (4).

Located just north of the Ohio-Erie watershed, or crest-line of the state, the Bucyrus Bog is about seventeen miles southwest of the first of the ice-front lakes, now surviving as the New Haven Marsh. It is about twenty miles northwest from a contact of the Wisconsin and Illinoian glaciation, being thus fairly near the last ice edge. While not so old therefore as bogs lying nearer the edge of the ice-sheet, this bog appears to date back nearly to the beginning of post-glacial time, and in any case it gives a record of those subsequent changes which have been most significant in the development of our present floristic complex.

The bog was covered with *Vaccinium* and surrounded by groves of *Quercus* and *Carya* when the country was settled early in the last century. Not more than one-half mile south, on the other side of the watershed, were extensive areas of *Andropogon* prairie, with scattered groves of *Quercus* and *Carya*. Only two miles north, *Fagus*, *Acer* and other mesophytic hardwoods had established themselves. Nowhere in the immediate vicinity were there any conifers, except such *Larix* as might have been in this or neighboring bogs.

PREVIOUS AND RELATED WORK.

For many years assumptions as to post-glacial climate in the Great Lakes region have been the simplest possible consistent with the known facts of a gradual fluctuating recession of a huge continental ice-mass. On this basis southern species were considered to be advancing, northern retreating, and isolated bog associations have been held to be relicts of a once continuous tundra. In other words, a general moderation of climate has been assumed.

At the same time, observers have known of the existence of western plants, or even associations, far east of their present

climatic region. As instances may be cited the occurrence of *Opuntia* on the south shore of Lake Erie, along the Illinois River, and the presence of extensive *Andropogon* prairies, surrounding islands of Oak-Hickory, across much of Ohio.

Had these areas been first investigated by strictly ecological rather than floristic methods it is possible that their significance might have been missed. Gleason (5), 1909, working in Illinois, approached the problem from a floristic standpoint, however. Ascertaining that forest was increasing at the expense of prairie before white settlement, he suggested that there had been a period of widespread continental climate in post-glacial time succeeded by a recent period of increasing humidity. Following the terminology of European workers, he used the word "xerothermic" to suggest that the period of continental climate had been dry and warm.

Dachnowksi (6) from a study of the gross characters of peat strata states tentatively that Ohio peats show an irregular series of changes, due to climatic influences. After discussing evidence which deals with fluctuations during the Wisconsin glaciation, he suggests that the last advance of the ice was followed by a prolonged warm and somewhat humid climate. "This appears to have been the period of invasion and wide dispersal of forest trees from the south, and of a more northerly distribution of certain species than is now recorded for them. As to the end of the late glacial time, the climatic characteristics from the last glacial recessions to post glacial and present conditions stand as yet considerably ill defined. The evidences indicate periods during which the climatic zones shifted again somewhat. There appears to have been a return to cooler and drier climatic conditions, followed by a temperate and more humid period than exists at the present time in the same localities. The present period is probably approaching a climate of rising temperatures and (or) decreasing precipitation." He makes clear, however, that the data are insufficient for more definite conclusions, for correlation of the various deposits in this country, or for drawing parallels with other countries.

In 1926 the writer presented a reconstruction of the native vegetation of Ohio (4). On floristic and successional grounds he inferred that western as well as northern species appeared to be receding from the region, and southeastern species advancing into it. In his opinion the retreat of western forms was the

more recent, suggesting a period of continental climate in post-glacial time. The survival of bogs and other considerations led him to the conclusion (p. 229) that this arid climate had been cool rather than warm.

Auer (7) in 1927 in classifying the peats of southeastern Canada concluded that certain synchronous layers had been formed under dry conditions and expressed the belief that some correlation with the climatic sequences of Europe was possible.

Lewis and Cocke (8) in 1929 reported a pollen-analysis of the Dismal Swamp peat in Virginia. The analysis is presented and discussed in detail, and while fluctuations and disturbances are recorded, extreme caution is observed in drawing deductions as to climatic significance. The general trend of the record is one of succession from an open sedge-grass marsh to a closed mesophytic forest. At the eight and four foot levels there were disturbances which reduced the percentages of trees. The present mesophytic climax forest begins at the one foot level. It may be pointed out in passing that there is nothing inconsistent here with the assumption of a recent increase in climatic humidity in eastern North America.

Draper (9) working in this laboratory has made preliminary studies of a number of Ohio bogs. Especially noteworthy is her report of a grass-sedge-composite interval at four feet in an otherwise forest profile in the New Haven Bog. This plainly suggests a period of dryness, not far back.

COLLECTION AND SAMPLING OF MATERIAL.

Samples were taken at six inch intervals with a Davis peat sampler. Four columns were taken in different parts of the bog. The samples were wrapped individually in paper and shipped to the laboratory.

The present cover of the bog is a mixture due to secondary succession—largely *Carex*, *Poa*, *Polygonum*, *Populus*, *Salix*. There has been some attempt at drainage, and fires have occurred at several times. In the case of two of the four columns the top layer had been destroyed by fire, but the other two gave an undisturbed sequence. Three of the columns were carried down through the marl to quicksand, a distance of fourteen feet in the case of the longest.

For study, a block was cut from the center of each six-inch piece, the outside being removed to prevent possible contamination. This block was boiled in 10% KOH, centrifuged,

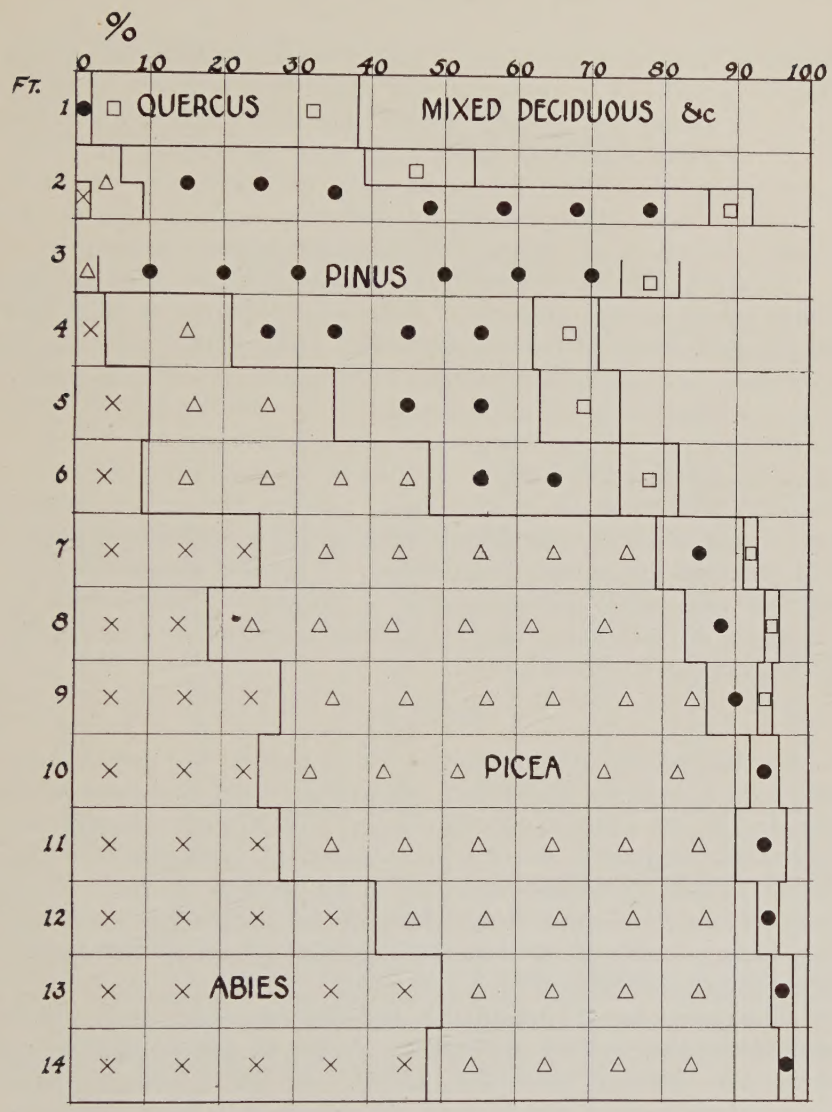

FIG. 1. POLLEN DIAGRAM OF THE BUCYRUS BOG.

At left is shown depth in feet, and across top is a percentage scale. Proportions of the four genera, *Abies*, *Picea*, *Pinus* and *Quercus* are shown for each level as they occur. Any remainder is designated as "Mixed Deciduous, etc." This includes some conifers, i. e., a little *Larix* and occasional *Tsuga*, a few herbs, e. g., *Typha*, *Graminales*, *Cyperaceæ*, but is mostly *Carya*, *Betulaceæ* and other deciduous forms. The break at 2′ 6″ represents a water pocket in the peat. In the 2′ level *Pinus strobus* replaces *P. banksiana* (and *resinosa*?). Distinct climatic equivalents are as follows: 12–14 feet—northern Labrador (cold, wet); 4–6 feet—southern Manitoba (cool, dry); 2 feet—northern Michigan (cool, moist); 1 foot—northern Ohio (increasing warmth and moisture). Generic symbols are the standard ones used by Erdtman who employs, however, graphs.

decanted, rinsed with filtered distilled water, centrifuged again and decanted. The material was then drawn up in a clean pipette, spread on a slide, dried and mounted in glycerine jelly. In strata like the lower marl and the weathered 3-foot layer where the pollen frequency was very low, the use of a centrifuge was indispensible in securing enough grains to count. At least two slides were prepared from each sample.

A key has been prepared (1) which includes most of the pollen found in this material. Wherever possible, at least 100 grains were counted from each slide. Only actual pollen was considered in figuring percentages, although spores of Sphagnum, & c. were tallied so that results could be computed if desired, as number per 100 pollen grains. It is believed that this is a more accurate procedure in dealing with cryptogamic spores than to add them in to the total. Pollen frequency (grains per sq. cm. of slide) was determined, and the presence of humified material roots and fungi noted. Valuable suggestions on method and some useful figures of American pollen will be found in the paper by Lewis and Cocke (8) as well as in the European papers cited in (1).

RESULTS.

In the accompanying tables I–IV are given the percentages of pollen at each six inch level. It will be noted that because of burning at the surface, columns 1 and 2 do not give as recent a record as columns 3 and 4 which extend to very recent times. Table VI is a condensed summary of all borings, by feet. This was obtained by connecting what, in my judgment, were corresponding levels of the four borings and grouping the results accordingly (see Table V).

The purpose of presenting the borings separately is to emphasize that pollen analysis is a clue to trends and in no sense an absolute statistical index. If the figures in each boring for *Quercus* are plotted all curves will have the same trend, but there will be no identity. Fluctuations of an order of 5-10% are to be expected. I have suggested *Quercus* because any errors in discriminating conifer pollens would not affect it. The same fact is clear, however, in comparing the conifers in those levels which were critically rechecked, and which are marked with an asterisk in the tables. But it should also be noted that while considerable fluctuation does occur at corresponding levels in different sections of the bog, *the principal*

trends are equally clear in each section. The critical points which will be shown in the consolidated graph of table V are all unmistakeable in the individual graphs of each column, if one cares to make them, as I have done in my own analysis of the data.

TABLE I.

POLLEN PERCENTAGES OF FIRST BORING.

Depth in inches‡	Abies	Picea	Pinus	Quercus	Other Genera	Pollen Grains	Pollen Frequency†
6*	05	14	49	05	27	257	60
12	01	17	43	07	32	136	167
18	00	27	47	07	19	120	81
24*	10	28	41	07	14	364	16
30*	04	33	38	08	17	342	27
36	0	22	30	10	38	92	24
42	01	32	29	05	33	110	17
48*	18	51	22	02	07	206	19
54*	23	59	13	01	04	222	33
60	05	75	09	03	08	112	37
66	10	75	07	02	06	100	37
72*	23	51	11	02	13	347	21
78*	26	71	02	00	01	360	126
84	13	84	02	0	01	123	82
90	17	76	04	0	03	118	132
96	25	70	01	0	04	106	160
102	32	61	02	0	05	122	70
108	47	49	02	0	02	129	143
114	45	53	02	0	0	131	157
120	47	51	02	0	0	118	175
126	48	47	02	0	03	121	120
132	50	41	05	01	03	109	21
						3,845	

‡Surface had been burned at this place.

*These depths were rechecked, as the numbers counted indicate. Some errors in determining coniferous pollen doubtless occurred in the original count, but the order of magnitude was small and the general trend not affected thereby.

†Grains per sq. cm. of slide. This has no standard significance, merely indicating order of relative abundance in the present study.

The results summarized in table V are diagrammed in figure 1. The most striking feature of this diagram, Fig. 1 is the successive appearance and waning of *Abies*, *Picea*, and *Pinus*, all finally supplanted in the youngest layers of *Quercus* and other deciduous trees. On its face is indicated a rise in temperature from the time the bog began to the present, with a rather recent period of maximum dryness expressed in the dominance of pine at the 4-foot level, and increasing moisture

since. That much may safely be inferred from a knowledge of the ranges and ecological characters of the various genera which are most conspicuous.

In terms of present-day climates, I consider the 12-14 foot, 4-6 foot, and 2 foot levels of critical importance. In the lowest

TABLE II.

POLLEN PERCENTAGES OF SECOND BORING.

Depth in inches‡	Abies	Picea	Pinus	Quercus	Other Genera	Pollen Grains	Pollen Frequency†
6	01	11	53	08	27	165	453
12	01	24	50	05	21	111	273
18	03	08	50	10	30	358	39
24	08	16	14	23	39	139	12
30	12	50	25	04	10	52	11
36	20	55	08	06	12	51	1
42	28	62	06	03	03	404	36
48	29	66	03	01	02	341	119
54	30	52	05	05	09	60	122
60	40	52	01	01	06	109	100
66	28	60	08	02	05	414	160
72	43	51	02	01	04	481	210
78	44	53	0	0	03	116	100
84	36	56	03	0	05	129	97
90	42	56	0	0	02	120	180
96	46	51	0	0	03	114	53
102	48	50	02	0	0	128	20
108	53	47	0	0	0	73	15
114	.....	.....	.....	.....	.....	0	.....
120	57	43	0	0	0	7	2
126	63	37	0	0	0	8	2
						3,380	

‡Surface had been burned at this place.

*These depths were rechecked, as the numbers counted indicate. Some errors in determining coniferous pollen doubtless occurred in the original count, but the order of magnitude was small and the general trend not affected thereby.

†Grains per sq. cm. of slide. This has no standard significance, merely indicating order of relative abundance in the present study.

levels, first mentioned, *Abies* and *Picea* both appear with a minimum of *Pinus*. This condition is found today (10) in the cold, oceanic, humid climate of northern Labrador, where *Pinus* appears not to withstand conditions as well as the other two genera. At the intermediate levels, notably the 7 foot level *Picea* and *Pinus* are most abundant, with much less *Abies* and some deciduous genera. This condition appears today in southern Manitoba, a cool, dry continental climate, where

Abies ranges west chiefly in the immediate vicinity of the larger lakes.

Until the two foot level, the species of pine appears to be *Banksiana*, with a characteristic small pollen, although *resinosa*

TABLE III.

POLLEN PERCENTAGES OF THIRD BORING.

Depth in inches	Abies	Picea	Pinus	Quercus	Other Genera	Pollen Grains	Pollen Frequency
6*	0	0	01	34	65	350	1,860
12*	0	01	02	46	52	444	640
18	0	07	19	15	60	137	252
24	.....	.....	.....	.....	.....	0	.....
30	.....	.....	.....	.....	.....	?	.....
36*	01	01	64	08	27	291	3
42	0	06	44	18	32	115	7
48	07	13	16	11	53	45	.....
54*	08	29	16	09	37	107	6
60*	19	40	16	09	15	158	7
66	0	52	21	10	16	42	9
72	0	42	42	0	15	69	11
78*	23	49	15	04	09	304	.....
84*	25	55	12	02	07	362	26
90	01	79	17	01	02	111	33
96	01	78	17	01	02	86	9
102	29	61	07	01	02	121	43
108	19	68	11	01	01	155	21
114	16	68	14	0	02	107	14
120	18	63	10	0	08	94	11
126	20	64	16	0	0	125	30
132	21	59	20	0	0	80	9
138	24	55	07	0	14	42	5
144	42	54	02	0	02	48	4
150	49	49	0	0	03	101	.....
156	61	28	11	0	0	18	20
162	34	66	0	0	0	3	0.3
						3,515	

*These depths were rechecked, as the numbers counted indicate. Some errors in determining coniferous pollen doubtless occurred in the original count, but the order of magnitude was small and the general trend not affected thereby.

†Grains per sq. cm. of slide. This has no standard significance, merely indicating order of relative abundance in the present study.

?Through error this level was not counted.

may also be present. In any case a continuance of cool xerophytic conditions seems clear. In the two foot level, along with an abrupt increase in deciduous genera, the species of pine changes to *P. strobus*, with a larger pollen. Although this pine is rated by Hutchinson (11) as fairly low in moisture

requirements, it is commonly regarded as the most mesophytic of the northern pines, and its appearance probably indicates an increase in humidity. Today *P. strobus*, with deciduous species, is found in the fairly cool, semi-humid region of the northern Great Lakes.

In the one-foot level *Quercus*, with *Carya* and other deciduous trees represents substantially the present vegetation. A trace of pine pollen appears, but no native pine is known nearer than

TABLE IV.

POLLEN PERCENTAGES OF FOURTH BORING.

Depth in inches	Abies	Picea	Pinus	Quercus	Other Genera	Pollen Grains	Pollen Frequency†
6*	0	0	02	26	73	421	?
12	0	01	02	46	50	129	530
18	0	05	46	16	33	125	625
24*	02	07	77	06	08	355	410
30	.....	.....	.....	.....	.....	0	?
36	0	0	74	10	17	111	190
42	0	07	77	06	11	124	140
48*	15	34	28	09	08	225	53
54	21	33	13	15	19	107	122
60	39	36	0	18	08	28	12
66	25	53	12	02	08	64	5
72	38	51	09	01	01	405	?
						2,094	

*These depths were rechecked, as the numbers counted indicate. Some errors in determining coniferous pollen doubtless occurred in the original count, but the order of magnitude was small and the general trend not affected thereby.

†Grains per sq. cm. of slide. This has no standard significance, merely indicating order of relative abundance in the present study.

about 35-40 miles within historical times. As compared with the preceding level the one-foot stratum indicates warming and probably further increase in humidity.

In other words the diagram indicates the following climatic sequence:

14–12 feet. Cold, wet climate of northern Labrador.
11– 7 feet. Gradual shift from oceanic to continental climate.
6– 4 feet. Cool, dry climate of southern Manitoba.
3–2.5 feet. Period of maximum dessication.
2 feet. Abrupt increase in humidity. Cool, moist climate of Northern Great Lakes.
1 foot. Moderation of temperature and continued increase in humidity, present climate of north-central Ohio.

TABLE V.

EQUIVALENCE OF BORINGS.

Equivalent Depth in Feet	Borings in Inches from Present Surface				Peat Character	Forest Dominants	Climate
	I	II	III	IV			
1	Destruction by fire and perhaps surface erosion		6 12	6 12	Brown Black	Oak, Hickory	Warmer, Humid
1–6			18	18	Coarse brown	Oak, Pine	Cool, moist
2–0			.....	24	"	Pine	
2–6			24	30	Water pocket		
3			*(30) 36	36 42	Clayey "	Pine	Cool, dry
4	6 12	6 12	42 48	48	" "	Pine, Spruce " "	Cool, dry
5	18 24	18 24	54 60	54	" "	" " " "	Increasing dryness
6	30 36	30 36	66 72	60	" "	Spruce, Pine	
7	42 48	42 48	78 84	66 72	Marly "	Spruce	
8	54 60	54 60	90 96	....	" "	Spruce	
9	66 72	66 72	102 108	....	Marl..... "	Spruce	
10	78 84	78 84	114 120	....	" "	Spruce	
11	90 96	90 96	126 132	....	" "	Spruce	
12	102 108	102 108	138 144	....	" "	Spruce, Fir " "	Cold, humid " "
13	114 120	114 120	150 156	....	" "	" " " "	" " " "
14	126 132	126	162	.....	" "	" " " "	" " " "

*Not included in count.

As confirmatory evidence of the dry conditions of the 4-2 foot level may be cited the low pollen frequency and the presence of numerous roots and much highly humified material. These plainly suggest a low water table and poor conditions for peat formation or pollen preservation.

The presence of clay in the peat deposited at the 6–3 ft. levels can, apart from the evidence of the pollen statistics, be construed with reasonable assurance as an evidence of increased dessication.

TABLE VI.

CONSOLIDATED SUMMARY BY FEET.

Feet	Abies	Picea	Pinus	Quercus	Other Genera	Total Pollen Grains Counted
1–0	0	0	02	36	62	1,344
1–6	0	6	33	15	46	262
2–0	02	07	77	06	08	355
2–6						0(water)
3	00	03	71	08	18	526
4	04	17	41	09	29	1,054
5	10	25	28	11	26	1,353
6	09	39	26	08	18	676
7	25	54	12	02	07	2,196
8	18	65	11	02	04	700
9	28	58	07	02	05	1,618
10	25	67	04	0	04	929
11	28	62	07	0	03	663
12	41	52	03	0	04	542
13	50	45	03	0	02	375
14	48	48	2	0	02	241
						12,834

It should also be noted that the unpublished work of Mr. George H. Lane on Iowa peats, carried out in this laboratory, confirms the above sequence in a striking way. In Iowa the period of gradual dessication caused a replacement of coniferous forest by prairie via deciduous forest. This prairie has been dominant since. But at the four foot level, corresponding to the *Pinus* period in Ohio, there is a strong increase in *Chenopodiaceæ* and *Amaranthaceæ* at the expense of grass. This suggests a xerophytic climax marked by strong evaporation and possibly alkaline or saline conditions in Iowa during the period of maxiumum dessication in Ohio. Above this level the grasses have again become dominant, additional confirmation of a recent increase in humidity.

In conclusion it appears that the climate of Ohio today is warmer than it has ever been since the Wisconsin glaciation. Since the continental maximum appears to have been cool, it seems inadvisable to use the term "xerothermic" to describe it, at least for the present.

SUMMARY.

1. Four cores were obtained in different parts of an old bog two miles east of Bucyrus, Ohio. Each one showed the same general trend of post glacial vegetation by means of the percentages of stratified pollen, counted at six inch intervals.

2. There was sufficient individual difference between cores to demonstrate that small fluctuations must not be regarded too seriously.

3. Corresponding levels in the four cores were readily located and the results grouped.

4. The sequence of vegetation appears to have been Abies-Picea, Picea-Pinus, (Pinus maximum), Pinus-Quercus, Quercus-Mixed Deciduous.

5. In terms of present local vegetation this sequence would be Northern Labrador, Southern Manitoba, Northern Michigan, Northern Ohio.

6. The sequence of climate to be inferred appears to be cold-wet Oceanic, cool-dry Continental, (Continental maximum) cool-moist Sub-continental, warmer-moister Sub-oceanic.

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THE LAWS OF MOTION UNDER CONSTANT POWER.

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The laws of motion under constant *force* form the door of introduction to the subject of Dynamics, for most elementary Physics students, and properly so. In these days of steam, electric and gasoline transportation, the laws of motion under constant *power* would seem to be only second in importance. This opinion is evidently not shared by authors of textbooks on mechanics, for in the course of several months search the writer has been unable to find a single reference to such a subject. In the meantime he has investigated the laws of this type of motion, and found that they were both surprisingly simple and remarkably easy of deduction.

The laws of motion under constant *force* may be completely described by three equations:

$$v = at \qquad s = \tfrac{1}{2}at^2 \qquad v = \sqrt{2as}$$

These equations are built on the assumption that the initial values of the variables are zero. The acceleration a is of course a constant, the value of which may be found from Newton's second law of motion, $f = ma$.

In the laws of motion under constant *power*, four variables (s, v, a and t) are involved, instead of three as in the preceding case. Six equations, each involving two of the variables, are necessary to completely describe the laws of motion. This is a consequence of the fact that the number of possible combinations of four things taken two at a time is six.

These six equations may be conveniently stated as follows:

$$a = \frac{P}{mv} \quad (1) \qquad v = \sqrt{\frac{2Pt}{m}} \quad (2) \qquad s = \sqrt{\frac{8Pt^3}{9m}} \quad (3)$$

$$a = \sqrt{\frac{P}{2mt}} \quad (4) \qquad s = \frac{mv^3}{3P} \quad (5) \qquad a = \sqrt[3]{\frac{P^2}{3m^2s}} \quad (6)$$

As before, the initial values of the variables are assumed to be zero. This is simply equivalent to saying that both distance

*Presented at the meeting of the Ohio Academy of Science, April, 1930.

and time are respectively measured from the point and instant of starting, which would, of course, be the natural thing to do. P, representing the constant power applied, must, like f in the preceding case, be measured in absolute units.

A deduction of these laws follows: By definition, $P = fv$ and $f = ma$. Combining to eliminate f, $a = \frac{P}{mv}$ (1.)

Substitute $a = \frac{dv}{dt}$ and restate equation 1 as follows: $vdv = \frac{P}{m}dt$ whence, integrating between the limits 0 to v and 0 to t respectively, $v = \sqrt{\frac{2Pt}{m}}$ (2.)

Substitute $v = \frac{ds}{dt}$ and restate equation 2 as follows: $ds = \sqrt{\frac{2Pt}{m}}\,dt$, whence, integrating between proper limits

$$s = \sqrt{\frac{8Pt^3}{9m}} \quad (3.)$$

Substitute equation 2 into equation 1 to eliminate v, whence,

$$a = \sqrt{\frac{P}{2mt}} \quad (4.)$$

Substitute equation 2 into equation 3 to eliminate t, whence,

$$s = \frac{mv^3}{3P} \quad (5.)$$

Substitute equation 5 into equation 1 to eliminate v, whence,

$$a = \sqrt[3]{\frac{P^2}{3m^2s}} \quad (6.)$$

In case it is not desired to subject the conclusions to the limitations involved in the assumption of zero initial values, the corresponding relations are readily deduced by the simple expedient of changing the values of the limits in the two integrations above.

Three of these relations are deduced without the use of calculus. Equation 1 was so derived above. In addition, one may utilize the principle of Conservation of Energy by writing

$$Pt = \tfrac{1}{2}mv^2 \quad \text{whence} \quad v = \sqrt{\frac{2Pt}{m}} \quad (2.)$$

Substitution of equation 2 into equation 1 gives equation 4, as before. The other three equations do not appear to readily yield to the freshman type of attack. It is a simple matter to show, however, by elementary methods, that the value of the distance in terms of the velocity, (equation 5) must lie between $\frac{mv^3}{2P}$ and $\frac{mv^3}{4P}$. And if it be considered allowable to conclude that the true expression is $\frac{mv^3}{3P}$ then the remaining equations follow.

A brief glance at some numerical cases may not be entirely without interest. Calculation shows that a fifty horsepower automobile weighing two tons will travel 444 feet the first ten seconds from a standing start, will acquire a velocity of 45.4 miles per hour and will possess at the conclusion of the ten seconds an acceleration of 2.3 miles per hour per second. For five seconds the corresponding figures are 156.6, 33.1, and 3.3, and for one second, 13.9, 14.9 and 7.35.

Perhaps it is unnecessary to add the caution that in these equations power must be expressed in absolute units. In the metric system this would be ergs per second, and in the English system foot poundals per second. If the British Engineers system is used, mass will of course be expressed in "slugs" and power in foot pounds per second.

This problem assumes an entirely different aspect if, in an attempt to represent the facts more closely, we introduce terms to account for friction, air resistance and the pull of gravity in going up or down grade. It then becomes essentially a problem of motion in a resisting medium, friction and gravity representing constant forces and air resistance a force closely proportional to the square of the velocity. Introduction of these factors leads to a differential equation which anyone may be pardoned for not easily solving. A discussion of it may properly form the basis for a later report. In the meantime, we have before us the laws of motion for constant *power*, corresponding to the three classical laws for constant *force*, which have always been so much in evidence in our work in mechanics.

PRIMARY NON-DISJUNCTION IN DROSOPHILA HYDEI.*

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College of Wooster.

INTRODUCTION.

Non-disjunction of the sex chromosomes has been recorded in several species of Drosophila. Bridges ('13) studied this phenomenon first in Drosophila melanogaster. A review of his work and that of other investigators is given by Morgan, Bridges, and Sturtevant ('25), with citations of papers published up to that time. In Drosophila simulans non-disjunction has been reported by Sturtevant ('21). Weinstein ('22) recorded its occurrence in Drosophila virilis and Lancefield and Metz ('21) have studied it in Drosophila willistoni. Recently Timofeeff-Ressovsky (work unpublished) has observed non-disjunction in Drosophila funebris.

From the standpoint of comparative genetics it seemed worth while to undertake a study of this phenomenon in Drosophila hydei. Furthermore the limited investigation of the species had resulted in the finding of several sex-linked mutants which gave promise of being unusually favorable tools in a study of this kind.

Reference to Figure 1 will show the tentative map of the x-chromosome and the mutants used. In order to represent the genetic map on a larger scale a long section of the map has been omitted as indicated by the break in each chromosome shown. The x-chromosome of this species is actually a long V-shaped structure according to the cytological investigation of Metz and Moses ('23).

Notched (N) at locus 0.0 was found by Spencer ('27). It is a dominant wing mutant, causing a thickening of the wing-veins, notching of the margins of the wings, and a lethal effect in males. It is presumably lethal also in homozygous females, though in the nature of the case a homozygous female could only be produced through equational non-disjunction as there are no Notch males to pass the factor on to their daughters.

*Presented at the meeting of the Ohio Academy of Science, April 18, 1930.

White (w) at 3.6, and vermilion (v) at 15.1 are recessive eye color mutants found by Clausen ('23).

Bobbed (b) at 62.6 was reported by Clausen ('23), and an allelomorph (b^2), was recorded by Spencer ('27). Clausen's bobbed was used in this study. Bobbed is characterized in homozygous females by a reduction in the size of the bristles and hairs in all parts of the body, and in Clausen's allelomorph by abnormalities in the pigment bands of the abdomen in some flies. It is ordinarily sex-limited. The male, which transmits the bobbed gene in its x-chromosome is entirely normal in appearance. Bobbed mutants, parallel both in the position of their loci in the x-chromosome and in being sex-limited are known in Drosophila melanogaster and in Drosophila simulans. In the latter it is the female which is normal in appearance. In an extensive and brilliant series of researches Stern ('26a, '26b, '27, '29a, '29b) has shown through the study of non-disjunction and other chromosome aberrations involving this mutant that the sex-limited nature of the mutant in Drosophila melanogaster is due to the presence of a bobbed suppressor or normal allelomorph in the Y chromosome. His work has not only demonstrated the presence of this inhibitor in the Y, but has shown it to be limited to a certain region of the Y-chromosome.

In work on the linkage of bobbed in Drosophila hydei (Spencer '27) a male showing the bobbed character in extreme degree was recorded and interpreted as a gynandromorph. This individual was sterile. Stern ('29b) has recently referred to this individual and analysed the case not as a gynandromorph, but as being due to non-disjunction in the male parent resulting in a sperm carrying neither X nor Y-chromosome, which on fertilizing an X-bearing egg produced this male with X composition and sterile through lack of the Y-chromosome.

PROCEDURE AND RESULTS.

As shown in Figure 1 females heterozygous for Notch, homozygous for white and bobbed, and carrying the wild-type allelomorphs at the vermilion loci were mated to males carrying the wild-type allelomorphs for Notch and white at their respective loci, the vermilion and bobbed genes in their X-chromosome, and presumably carrying the bobbed suppressor in the Y-chromosome. From such a cross three classes of offspring would be expected to occur in about equal numbers:

white-eyed, normal-winged, phenotypically normal-bristled males; mahogany-eyed (wild-type), Notch-winged, bobbed-bristled females; mahogany-eyed, normal-winged, bobbed–bristled females. Reference to Figure 1 will make this clear. The fourth genotypic class, the white Notch males do not appear among the phenotypes, due to the lethal action of Notch. Table 1 gives the actual results of counts of the offspring from 146 cultures of the above cross.

TABLE I.

THE OFFSPRING FROM 146 SINGLE MATING CULTURES OF NOTCH, WHITE, BOBBED FEMALES TO VERMILION, GENOTYPICALLY BOBBED MALES.

Phenotypic Classes	Number of Flies
White-eye, normal-wing, normal-bristle males	4,735
Mahogany-eye, normal-wing, bobbed-bristle females	5,067
Mahogany-eye, Notch-wing, bobbed-bristle females	4,482
White-eye, Notch-wing, normal-bristle females	7
Vermilion-eye, normal-wing, extreme bobbed males	3
White-eye, normal-wing, extreme bobbed male	1
White-eye, normal-wing, normal-bristle female	1
Vermilion-eye, normal-wing, bobbed-bristle female	1
Total Flies	14,297

EXPLANATION AND DISCUSSION.

In Table 1 of the total of 14,297 offspring all but 13 belong to the classes expected. The three expected classes occur in approximately a 1 : 1 : 1 ratio. As is usually the case in counts involving Notch this class is somewhat lower than the others, due to a lessened viability of the Notch flies. It should be stated that the bobbed character is not always easy to identify in females and there is some tendency to overlapping of the wild-type. However, in most of the individuals it could be distinguished and all females of the mahogany Notch and mahogany normal-winged classes have been classed as penotypically bobbed.

The seven white-eyed, Notch-winged, normal-bristled females and the three vermilion-eyed, normal-winged, extreme bobbed males are due to non-disjunction of the X-chromosomes of the female parent. This is made clear by reference to Figure 2. In non-disjunction of the reductional type the two X-chromosomes of the primary oocyte may either go into the second-

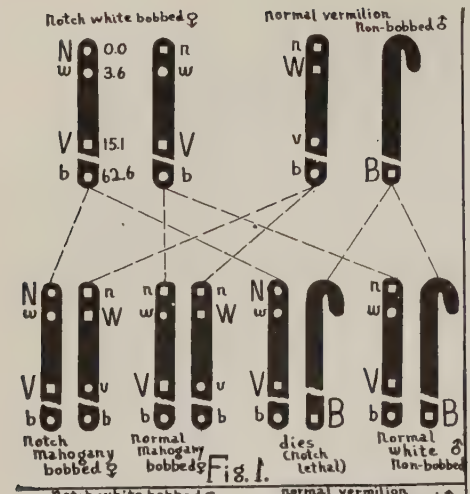

Fig. 1.

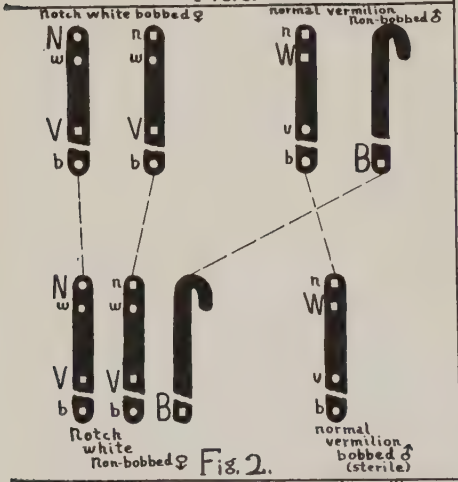

Fig. 2.

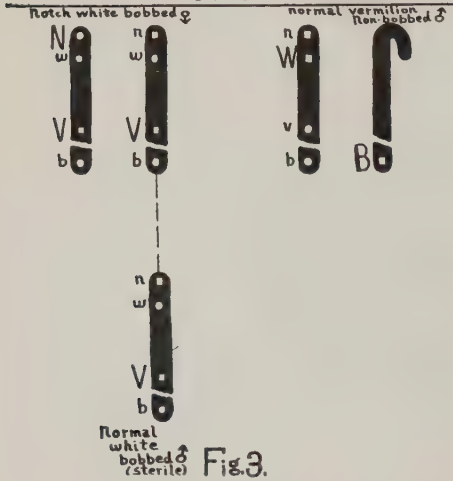

Fig. 3.

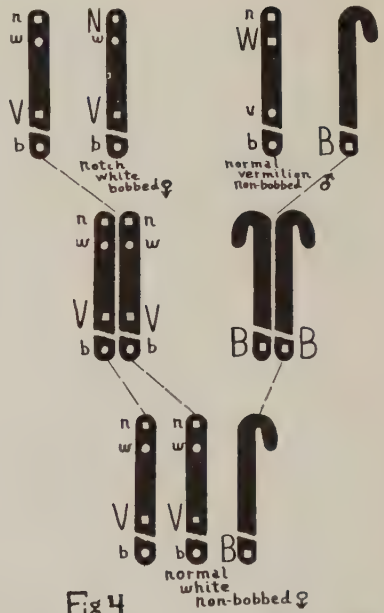

Fig. 4

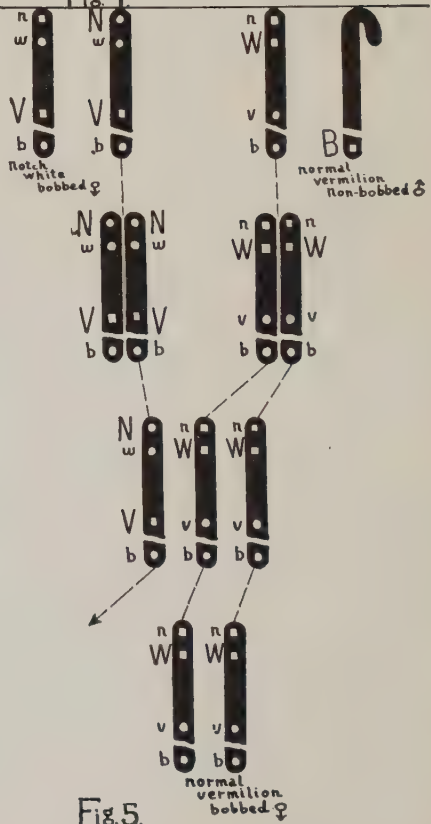

Fig. 5.

ary oocyte together or they may be expelled together into the first polar body, leaving the secondary oocyte without any X-chromosome. When an egg containing the two X-chromosomes of the mother is fertilized by a Y-bearing sperm a female is formed, with an XXY constitution as indicated by the offspring to the left in Figure 2. These females are Notch and white-eyed like their mothers, but as they each carry a Y-chromosome they are not bobbed like their fathers. When an egg without either X is fertilized by an X-bearing sperm a male is produced, XO in composition, vermilion-eyed and normal-winged like the father, but showing the bobbed character as the Y-chromosome with its bobbed suppressor is not present. The genotype of such an individual is shown to the right in Figure 2. In Drosophila melanogaster it has been shown that XO males are always sterile. The three vermilion, extreme bobbed males were mated each to several sisters but all proved to be sterile. Thus the XO composition of these males is shown by their eye-color, their possession of the bobbed character in extreme and unmistakable form, and their sterility.

The explanation of the one white-eyed, extreme bobbed male is to be found in Figure 3. In this case non-disjunction in the male parent resulted in the formation of a sperm with neither X nor Y-chromosome present. When this sperm fertilized an egg bearing a single X with the white, normal-

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EXPLANATION OF FIGURES.

Fig. 1. The sex-chromosome composition of a Notch, white, bobbed female and a normal-winged, vermilion, phenotypically non-bobbed male and of the classes of offspring to be expected from them when normal disjunction of the sex-chromosomes occurs in both parents.

Fig. 2. The two classes of offspring resulting from primary non-disjunction of the reductional type. The XXY female produced by fertilization of an XX egg by a Y sperm and the XO sterile male coming from the fertilization of an egg bearing no X by a sperm carrying an X.

Fig. 3. A sterile male produced by primary non-disjunction of the reductional type in the male parent. An X-bearing egg fertilized by a sperm carrying neither X nor Y and due to reductional non-disjunction in the male parent.

Fig. 4. An XXY female due to primary non-disjunction of the equational type in the female parent.

Fig. 5. A patroclinous female receiving her two X chromosomes from the male parent as a result of equational non-disjunction in this parent followed by the elimination of the maternal X as shown by the arrow.

NOTE.—The X chromosome is represented as a straight rod, the Y chromosome as a hooked rod. The break in the chromosome represents a long section of the genetic map left out. The squares represent the normal or wild-type factors or genes and the circles the mutant factors.

winged and bobbed genes in it a male of the above phenotype was produced. This XO male was sterile. The use of the bobbed mutant makes it possible to detect non-disjunction in the male. If the bobbed character were not being followed non-disjunction could occur in the male without detection, as individuals from non-disjunction sperm would not differ phenotypically from those which had come from ordinary sperm. Stern ('27, '29b) has recorded non-disjunction in the male in bobbed stocks of Drosophila melanogaster.

The one white-eye, normal-winged, normal-bristled female is accounted for by equational non-disjunction of the not-Notched chromosome of the female parent as shown in Figure 4. Equational non-disjunction, while not as common as that of the reductional type, has been repeatedly recorded in Drosophila melanogaster. In the present instance the heterozygous Notched condition of the female parent makes it certain that the non-disjunction was of the equational type. A possible alternative explanation of this individual would be that of gynandromorphism. The not bobbed condition might then be due to normal overlapping of the bobbed character. The female might have received one X-chromosome from the father and one from the mother. The paternal X might have been eliminated from an early cleavage cell, from which all eye tissue developed. This would give a gynandromorph, female posteriorly and male and with white eyes anteriorly. Such a gynandromorph would, however, have produced sons half of which would have been white and the other half vermilion. This female on being bred produced only white-eyed sons, showing that she was homozygous for white. This fact proved that both her X-chromosomes were derived from her mother. They must have come from the not-Notched X through non-disjunction at the equation division, as the fly was not Notched.

That none of the seven Notched white females recorded above were due to equational non-disjunction of the Notch bearing chromosome was shown by breeding tests. Had any of the above flies been homozygous for Notched through equational non-disjunction they should have given only Notched daughters and no sons at all. As none of them gave this result on breeding it seems clear that each of the seven was due to reductional non-disjunction. This is in accord with the implication that homozygous Notched females would be lethal as are Notched males.

The patroclinous vermilion-eyed, normal-winged, bobbed female presents some difficulties. In Figure 5 a formal explanation of how such an individual might have occurred is given. It must be supposed that equational non-disjunction has occurred in the male, resulting in a sperm with two paternal X-chromosomes. This sperm fertilizes either an egg which through non-disjunction lacks an X or an X-bearing egg. In the latter case there is elimination of the maternal X soon after fertilization resulting in a female homozygous for the sex-linked factors of her father. The simultaneous occurrence of non-disjunction in male and female gametes seems an event so extremely rare that we may disregard it in favor of the alternative of non-disjunction in the male followed by somatic elimination of one of the three X-chromosomes (in this case the one maternal X) from the zygote. While there is little evidence on the point it would not seem unlikely that the presence of an extra X-chromosome in the zygote might favor the loss of an X during an early cleavage stage. Mrs. L. V. Morgan ('22) has shown that the female from which the double yellow stock with attached X-chromosomes has been derived was a mosaic due to somatic elimination of the maternal X from a fly which had arisen from an equational non-disjunction sperm fertilizing an X-bearing egg. She cites two additional cases (L. V. Morgan '29) in Drosophila melanogaster in which this sequence of events has occurred. The alternative explanation of gynandromorphism in our present case was shown to be invalid by breeding tests. All sons from this female were vermilion showing that the fly was homozygous vermilion.

The data presented here give about one individual in 1100 from primary non-disjunction of the sex chromosomes. This is a somewhat higher percentage than that given for Drosophila melanogaster by Morgan, Bridges and Sturtevant ('25). However, the data in our present study are insufficient to give an accurate idea of the relative frequency in the two species. Mrs. Morgan ('29) has suggested that Notched and bobbed may both tend to increase non-disjunction. Whether this be true or not they do favor its study and analysis. It is significant to find that primary non-disjunction in this species gives rise to essentially the same phenomena, especially in the case of bobbed, as are found in Drosophila melanogaster.

Secondary non-disjunction is at present being studied in this species and will be reported on at a later date. It may be

said that the secondary exceptions are apparently of a much lower frequency than in other species studied.

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NEW REPORT ON NEW BRUNSWICK.

The Canadian Department of the Interior has just issued a beautifully printed and illustrated report on New Brunswick of 166 pages, with 33 photographs, 10 sketch maps and a general map in color. "The potentialities of this maritime province have undoubtedly been overlooked during the period of the agricultural development of Western Canada and the industrial growth of Ontario and Quebec, for it is only recently that its water-powers and forest wealth have been utilized in large-scale pulp and paper enterprise. Progress in this direction has indeed been remarkable. Last year the largest power site in the Maritimes was developed at Grand Falls, with an installation of 60,000 horse-power and transmission line of 104 miles to Chaleur Bay; 5,500 horse-power was added to the 9,000 horse-power already developed on the Nipisiguit; the capacity of the plants at Edmundston and Bathurst were enlarged; while a newsprint mill with an initial daily capacity of 250 tons came into operation in March, 1930; and a bleached sulphite mill at Athol has lately been completed.

"A similar awakening is in evidence in regard to the fertile and cheap agricultural lands, minerals and fisheries, and the many recreational attractions of the province, all of which resources and the development opportunities they present are dealt with in this governmental publication, which can be obtained from the Director, Natural Resources Intelligence Service, Department of the Interior, Ottawa."

INTERNAL ANATOMY OF EURYURUS ERYTHROPYGUS (BRANDT). (DIPLOPODA).*†

HUGH H. MILEY.

Introduction.

In a previous paper the writer (1927) reported the results of observations upon the development of the male gonopods, distribution and life history studies of *Euryurus erythropygus* (Brandt), a Polydesmid millipede, which lives on decaying wood.

A review of the anatomical literature on Diplopods revealed no information concerning the internal anatomy and physiology of *Euryurus*. Anatomical studies available were mainly on European forms, mostly of Germany, and with relatively little included on the *Polydesmidæ*. The literature on investigations concerning the digestion and embryology of the alimentary tracts of the Myriapoda, as well as some other studies, is rather meager. There exists no connected description of the Diplopods or Chilopods. The anatomical studies of Attems (1926), Randow (1924), Verhoeff (1910–1915), and (1926), in Bronn's "Tier-Reich," Effenberger (1909), Wernitzsch (1910) and Rossi (1901), (1902) are the most extensive and important for Diplopods. The best bibliographies were found in the references by Latzel (1884), Attems (1926) and in Bronn's "Tier-Reich" (1926).

The whole subject of arthropod histology during moulting and metamorphosis is rather obscure and there are often as many interpretations as there are investigators.

This paper deals with the internal anatomy of *Euryurus*, the histology of the mid-intestine during ecdysis and feeding condition, fauna found in the intestinal canal and especially with the body, leg and mandible musculature and the gross and histological anatomy of the digestive tract. A comparison with the anatomy of other *Polydesmidæ* and *Julidæ*, already studied, showed differences and similarities.

*Dissertation presented in partial fulfillment of the requirements for the Degree of Doctor of Philosophy in the Graduate School of The Ohio State University.

†Contribution No. 103 from the Department of Zoology and Entomology, Ohio State University.

Leidy (1851) first called attention to the extensive floral and faunal association within the ventriculus, the large intestine and rectum of *Spirobolus marginatus*, a millipede, which, like *Euryurus*, lives on decaying wood. His description of the alimentary tract will be included in the discussion of the tract of *Euryurus*.

In all specimens of *Euryurus* in which the intestinal tract was examined flora and fauna were found. The fauna found are as follows: Gregarines in the fore-intestine (genus and species not identified); *Nyctotherus velox*, a protozoan, in the hind-intestine and rectum.

The nematodes *Rhigonema infectum*, *Thelastoma attenuatum*, identified by N. A. Cobb, were found in the posterior part of the mid-intestine and the anterior portion of the hind-intestine. The malpighian tubules are located on a portion of a constricted area (Plate III, Fig. 4). As many as fifteen nematodes were found in a small area just preceding the constriction and as many as twenty-six in a small area following it.

Mites as ectoparasites were observed in a few cases.

A few investigators have studied the physiological relationship of many insects to organisms, but the writer has found nothing of a similar work on the Myriapoda.

Material and Technique.

The animals used were collected near Oxford, Ohio, although a few were found around the vicinity of Columbus and Lancaster, Ohio. Attention is called to a wider distribution of this organism than previously reported by the writer (1927). Many adults and especially a large number of moulting and non-moulting larvæ, of all stages, were found in their natural surroundings by the writer at Oxford, the latter part of August (1927). The millipedes are easily kept in the laboratory and breed in the somewhat artificial environment described by the writer (1927). An abundance of material was available for study, including adults and the seven larval stages.

Many difficulties have been encountered in these studies, both in gross dissections and histological technique. The feeding animals, especially adults and later larval stages, besides being small and flat have an extremely thick, hard and brittle chitinous exoskeleton and the underlying extremely delicate tissues adhere closely to the chitin. *Spirobolus margi-*

natus, a much larger, cylindrical millipede, is much easier to work with because of its size, shape and flexible chitinous body wall.

The internal anatomy described has been determined by careful gross dissections of feeding adults, moulting and non-moulting larvæ, using binocular microscope, and by serial transverse and longitudinal sections of entire animals. Serial longitudinal sections of all stages were prepared.

Material fixed in Carl's or Henning's or Gilson's fluids gave good results. Delafield's hematoxylin and eosin were used for ordinary studies and Heidenhain's iron hematoxylin for cytological work, with sections cut from 3 to 5 microns in thickness. Sudan III was used in testing for fat. Euparol, used instead of balsam, was also found valuable.

Photomicrographs of histological details have been taken and drawings made using a micro-projector drawing apparatus in vertical position.

INTERNAL ANATOMY.

The Alimentary Canal.

Effenberger (1907), (1909), Verhoeff (1914), (1910-1915), Attems (1926) have made rather extensive observations on European *Polydesmidæ*. Effenberger (1909) compared *Polydesmus* with *Julus* studied by Krug (1906). The outstanding works on *Julidæ* are by Plateau (1876), Voges (1878), Visart (1894), Krug (1906), Verhoeff (1910-1915), Randow (1924). Randow (1924) made the most extensive comparisons regarding the morphology and physiology of the intestinal canals of *Julidæ*.

Leidy (1851) gives a short description of the alimentary tract using a slightly different terminology from that generally used at present. Considering, as with the insects, that the attachment of the Malpighian tubules is a landmark in marking off the hind-intestine from the mid-intestine, the proventriculus as used by Leidy consists of the fore-intestine and the mid-intestine, which includes the ventriculus or true stomach. In *Polydesmidæ* and *Julidæ* the hind-intestine commences with a ring fold shown as (RF) in Plate III, Figs. 4, 4-C. This ring fold is slightly anterior to the attachment of the Malpighian tubules.

The ventriculus according to Leidy is a part of the hind-intestine, since it is set off from the mid-intestine by the attachment of the Malpighian tubules and is lined with a chitinous intima. Leidy called the Malpighian tubules biliary tubes and the hind-intestine the large intestine.

The later writers on *Polydesmidæ* and *Julidæ* divided the tracts into three main divisions, namely, fore-, mid-, and hind-intestine.

The intestine of *Euryurus* shows some similarities with and some differences from similar studies on European *Polydesmidæ* and *Julidæ*.

The Gross Anatomy of the Adult Canal of *Euryurus*.

The alimentary canal of the adult *Euryurus* shows considerable specialization in form and structure. It extends in almost a straight line from mouth to anus and is very large and capacious in relation to the size of the animal, in accordance with the nature of the food. There is a general rule that in herbivorous insects the alimentary tract is longer or more capacious than in carnivorous insects. In the local Myriapoda, the digestive tract has, for the most part, a greater circumference in the Diplopods. Three chief divisions of the tract of *Euryurus* are readily recognized, the fore-intestine (stomodeum), the mid-intestine (mesenteron or ventriculus), and the hind-intestine (proctodeum). The general form of the external gross anatomy is shown in Plate III, Fig. 4, and of the internal gross Anatomy in Plate III, Fig. 4. The natural lengths of three portions of the photographed alimentary tract were as follows: fore-intestine = 5 mm.; mid-intestine to Malpighian tubules = 13 mm.; Malpighian tubules to anus = 16 mm.

The oseophagus is a comparatively short slender tube, lined with a chitinous intima, extending to about the fourth trunk segment. Here it enlarges and connects with the mid-intestine. Internally at this junction there is a projecting valve which is formed by a padded girdle composed of six cushions or elevations each of which has a ridge in the middle extending into a point. These points (P) are quite long and bend outward into the lumen. (Plate I, Fig. 3 and 4-C). There is a ring furrow in front of the girdle. As many as twelve long rods, attached anteriorly in the oesophagus, have been counted projecting into the mid-intestine. Two, curving to a common attachment in the oesophagus, were noticed in some specimens.

The mid-intestine is a rather long, capacious, straight tube and is ochreous yellow in color. It is almost uniform throughout in size and usually smooth, although some irregular folds were noticed. The intestine commences to decrease in diameter a short distance anterior to the entrance of the Malpighian tubules. Where this narrowing begins there is a noticeable internal thickening encircling the intestine. A gross internal examination reveals a ring fold or valve and a ring furrow. (RF) (Plate III, Fig. 4-C). This marks the commencement of hind-intestine and the Malpighian tubules enter the intestine a short distance posterior to the ring fold. For insects the attachment of the Malpighian tubules is considered as the landmark in setting off the hind-intestine from the mid-intestine. Verhoeff (1910-1915) states that the ring fold is absent in European *Polydesmidæ*. The mid-intestine and its digestive epithelium terminate abruptly, being followed immediately by hind-intestinal epithelium. Sometimes there is a thickening of the muscle layers at this junction and it is spoken of as the pyloric valve in insects. In *Euryurus* there is considerable thickening of muscle layers posterior to the ring fold and which continues a short distance posteriorly. This, by Attems (1926), was called a closure valve (Verschlussklappe) in *Julidæ*. This portion Leidy called the ventriculus and it is short, cyclindrical and much narrower and stronger than the mid-intestine. Upon its exterior surface it is smooth.

Internally, as with the oesophagus, a series of longitudinal folds were noticed in the chitinous intima, and long rods, resembling those found in the oesophagus, were observed in this region.

Verhoeff (1910-1915) has discussed the hind-intestine of certain European *Polydesmidæ*, comparing them with the *Julidæ*. Krug (1906) divided the hind-intestine of *Julidæ* into three sections. Verhoeff divided the hind-intestine of *Julidæ* into five sections, namely, a urine chamber, fold chamber, wrinkled chamber, pre-anal constriction and rectum. The long main chamber of the hind-intestine of *Polydesmidæ*, he compared to the fold chamber and wrinkled chamber of *Julidæ*. Randow (1924) found five sections but he called the first "*Verschluss-klappe*" or closure valve.

In *Euryurus* the hind-intestine is narrow for a short distance posterior to where the Malpighian tubules enter it. It widens rather abruptly and continues about the same size to the pre-anal constriction, and again widens into the rectum. The hind-intestine is stronger than the mid-intestine and externally presents some irregularities such as indentations and slight folds, and is dark brown in color, for the most part. Internally a urine chamber, a fold chamber, a pre-anal constriction and a rectum are present. However, these sections vary in many respects from those of European *Polydesmidæ* and *Julidæ* observed by others. At the ring fold there are numerous longitudinal elevations and depressions. Larger longitudinal folds are seen in the narrow region and these continue to the fold chamber which in *Euryurus* is characterized by numerous small, dark brown papilla-like structures which have not been described in the literature reviewed. The pre-anal constriction presents a chitnous intima with longitudinal folds.

The writer (1927) named the mouth parts and described some aspects of the external anatomy of *Euryurus*.

The Histological Structure of the Fore-Intestine.

Oesophagus.—A pharynx is not referred to in the literature reviewed but Effenberger (1909), Verhoeff (1910-1915), Attems (1926) describe the fore-intestine as being hexagonal in shape behind the mouth opening. This is true for *Euryurus* but further posteriorly a cross section presents a different picture.

The fore-intestine for its entire length has a heavy chitinous lining continuous with that of the body wall. This chitinous cuticula is of uniform thickness but the epithelium and muscles vary some in the different regions. Near the mouth opening the epithelium consists of a definite, thin layer of small irregular cells. Further posterior the epithelium gradually thickens to the region characterized by a series of usually six longitudinal folds (Plate I, Fig. 1 and Plate II, Fig. 1).

The primary intima is well developed. The secondary intima underneath is almost transparent.

The epithelium consists of irregular elongate cells, whose nuclei located near the bases contain deep staining chromatin material. A basement membrane is present. (Plate I, Fig. 2.)

The longitudinal muscles start near the mouth and are most numerous at those points where the epithelium invaginates. They do not

all run directly longitudinally, but some intervene, so that cross-sections of this region show some of them running in an oblique fashion. All sections prepared show that the space between the epithelium and the circular muscle layer is not completely filled by these longitudinal muscles. Tracheoles were present, scattered among the longitudinal muscle fibers and what Effenberger (1909) and Krug (1906) called a homogeneous connective tissue. No connective tissue cells were observed in *Euryurus* as Krug (1906) reports for *Julus*.

The circular muscles form a layer outside the longitudinal muscles. This layer varies somewhat in thickness and completely surrounds the tract. Striations are easily observed here as well as in muscle of other portions of the tract except in the mid-intestine. Visart (1895) concluded from his studies on other forms that all the muscle in the intestine is striated. Randow (1924) seems to have the same opinion in regard to Julidæ.

Oesophageal Valve.—The fold of tissue composing this valve lies in the transition from the fore-intestine to the mid-intestine. (Plate I, Fig. 3). The gross appearance has been previously described by the writer. Effenberger (1909) merely mentions the presence of a valve in *Polydesmus*. Intima, epithelium, basement membrane, longitudinal and circular muscle fibers are present. The main structure of the fold is similar to that of the oesophagus.

The intima ends at (A) on the posterior surface of the fold which marks the limits of the fore-intestine.

The epithelium of the anterior face of the oesophageal valve continues much the same as in the oesophagus until just before reaching the tip of the fold. Here the cells gradually elongate until the end of the fore-intestine is reached. The epithelial cells of the mid-intestine are cuboidal at the annulus where they commence. A short distance back they are higher and rod-shaped. The basement membrane is continuous from the fore-intestine to the mid-intestine.

The longitudinal muscles of the fore-intestine end near the base of the fold. On the posterior surface of the fold the inner longitudinal muscles of the mid-intestine commence. They are fewer in number and smaller than those of the fore-intestine.

The circular muscles of the fore-intestine end near the annulus on the posterior surface of the oesophageal valve. The circular muscles of the mid-intestine appear soon after the inner and outer longitudinal muscles of the mid-intestine begin. They form a continuous layer.

The Mid-Intestine.

The mid-intestine or ventriculus is an elongated tube and is almost of uniform size. (Plate I, Figs. 4, 5). Its lumen is considerably larger than that of the oesophagus and is without folds. The histology of this portion of feeding animals varies in some respects from that of moulting forms so will be described separately.

A. Feeding Condition.

Cross sections of tracts of feeding animals showed the condition indicated in Plate I, Figs. 4, 5 and Plate II, Fig. 2. Towards the

lumen the epithelial cells are covered by a rod-like fringe. (CSB). This extends from behind the oesophageal valve at the anterior end of the mid-intestine to within the hind-intestine. Many times one observes a separation of the fringe but in many places it remains in position. The rods do not stain with eosin.

A membrane analogous to the peritrophic membrane of insects is present in *Euryurus* but the cuticula is distinct and separate. In the insects the usual explanation given is that this process of formation continues indefinitely and the peritrophic membrane shrinks around the food in the lumen of the intestine, while new membranes are repeatedly being formed by the discharging epithelial cells.

The epithelium is composed of a single layer of small cylindrical cells which appear like a fringe of very small rather uniform rods located on a tunica propria or basement membrane.

Some of the cells are larger towards the lumen. The growing cells push themselves between the old cells. Mucous cells as found by Balbiani (1890) in *Cryptops* were not observed in *Euryurus* nor did Randow (1924) find them in *Julidæ*.

Secretion is holocrine, that is, the entire cell contents are discharged into the lumen of the gut.

The cells, in *Euryurus* have comparatively large nuclei, nucleoli, chromatin lumps and contain much granulated secretion. The cell membranes in thin sections are usually very distinct. On the distal borders of the cells a thin homogeneous, non-alveolar edge is found under the rod-like fringe.

The tunica propria or basement membrane is a smooth or slightly waved lamella. It cannot be easily differentiated from the layers of circular muscle which follow.

Outside the two circular muscle layers is found a layer of cells which Plateau (1876) and Visart (1895) called adipose tissue in the forms they studied. Rossi (1902) and Leger and Duboscq (1904) are against this opinion. Krug (1906) called it "Drusenschicht" or glandular layer and Randow (1924) prefers the more general names "Hullschicht" or "Leberschicht" designated by Verhoeff (1910-1915) as the function of this layer is in many respects that of a liver. Fixing with osmic acid in a number of cases has not shown it to be a fat network. Sudan III proves the presence of fat in some cases.

This, in *Euryurus*, is a single layer (H) which is found over the entire mid-intestine. The cells are of various sizes. Its structure is compact just as Krug (1906) and Randow (1924) observed in *Julidæ* but Verhoeff (1910-1915) described it as being loose. The nuclei are spherical and show chromatin lumps in connection with the nuclear membrane and nucleoli. Frequently open spaces were observed where presumably xylol had dissolved the fat.

Yellow granules of various shapes are very characteristic in the covering layer.

The writer observed an increase of granules after specimens of *Euryurus* were starved for some weeks. Possibly the granules were excretory material but tests for uric acid and guanin were negative as were tests for albumen and stored iron.

No such layer, in a similar position, is found in insects.

In *Euryurus*, what is thought to be internal small longitudinal muscles surrounded by clear spaces are present at regular intervals in the portion of the network near the layer of circular muscle.

External groups of longitudinal muscle were observed outside and attached to the network.

The intestine of *Euryurus* is surrounded by numerous fine tracheoles. The tracheoles frequently pierce the network as is indicated by small, spherical bodies with clear spaces observed in sections.

B. Moulting Condition.

The condition of the mid-intestine of a specimen in the seventh larval stage which had just shed its exoskeleton is shown in Plate II, Fig. 3. This condition has been observed only in moulting or just moulted specimens of all seven stages of *Euryurus* sectioned. Gross dissections and microscopic sections of many specimens have disclosed no such condition in the tracts of feeding animals. The bodies labelled (DC) have been grossly dissected from moulting specimens. The bodies apparently not containing nuclei but concentric optical rings were not green in color but in view of the possibility that they might be algæ or fungi, cultures were tried, using plain agar agar and nutrient agar media and filtered lake water to which had been added decaying wood and heated to boiling. After many attempts these bodies were not successfully cultured. That some of the bodies are slightly phagocytic has been shown by experiments, using India ink and carmine, as they ingested small droplets of the ink or carmine. That the condition is not seasonal has been shown by sections of animals made during summer, fall, winter and spring.

The preceding observations seem to indicate that the condition is connected with the process of moulting and its associated phenomena. It is apparent that if this be true the process is very intricate. At any rate many questions concerning it are yet unsolved.

The bodies (DC) may be digestive cells given off from the old epithelium of the mid-intestine. It appears also that there has been a regeneration of the entire mid-intestine epithelium and that an old epithelial ring (AE) lies inside the outer tube. The cells have been observed multiplying amitotically in the inner ring.

In serial cross sections a pocket begins ventrally and anteriorly. (Plate I, Fig. 15-A). This is outside the circle of a tomodeal epithelium. Followed posteriorly, the pocket widens, and soon the stomodeal wall is interrupted ventrally (Plate I, Fig. 15-B). Continued posteriorly, the discontinuous stomodeal ring shrinks dorsally, and a crescent of other epithelium expands dorsally, until finally the former disappears and the entire tube is composed of the epithelium continued backward from the outer wall of the original pocket. (Plate I, Fig. 15-C).

This can only mean that the pocket is the anterior end of the ventricular lumen outside the lower lip of a short preventricular fold between stomodeum and mesentoron, or ventriculus. The same structure occurs in insects; the preventricular fold may be a mere rim at the anterior orifice of the stomach, or a long funnel-like tube. In

Euryurus it is very short, and the opening slopes from above forward and downward.

Verhoeff (1910-1915) in his eighth number of "Die Diplopoden Deutschlands" described his observations and those of vom Rath (1890) briefly in regard to the relations of the intestinal tract to moulting and above all to the characteristic phenomena which he designated as "leucocyte flood." His statements are mainly relative to *Iulidæ*, while *Polydesmus* and *Craspedosoma* are only briefly treated. Most of his material regarding *Polydesmus* is in a special article (1914) devoted to the transformation of the mid-intestine in *Polydesmus* during the moulting periods. A series of *Polydesmus monticolus vallicolus* Verh. larvæ in stages of moulting were observed and differences from conditions in *Iulidæ* were recorded and a few physiological factors considered.

Verhoeff stated that his theories concerning mid-intestinal histolysis show many loop-holes, which, he commented, is not surprising as it has never been observed before and is a very intricate process. It is true that many questions are yet unsolved. Verhoeff claims that the spheres are not digestive droplets because they are much larger and often nucleated and have the same appearance as leucocytes.

Randow (1924) in his studies upon espithelial regeneration did not include observations during moulting. In *Julus* he states that the renewal of epithelium takes place through "Blastemzellen" found over the entire mid-intestine as previously mentioned.

Randow and Verhoeff are the only workers who have made observations upon the epithelial regeneration in *Julidæ*. Randow objects to Verhoeff calling the epithelial cells leucocytes, a name which he thinks should be reserved for bodies in blood and body cavity fluids. Otherwise he is in agreement with Verhoeff's observations of regeneration during the non-moulting condition.

Hundreds of sections through the mid-intestine of just moulted specimens of *Euryurus* showed the condition as shown in Plate II, Fig. 3. There were two layers of epithelial cells and in between large numbers of spherical bodies of various sizes and some in clumps. They show concentric optical rings but apparently no nuclei. If present nuclei are not clearly defined. The cells of the outer epithelium are regular and key-like in arrangement. Cylindrical cells lie next to and near this layer. The epithelial layer lying in the lumen is in a stage of degeneration and has lost its cellular nature. Verhoeff called this the yellow layer. The dissolution of this layer and cells forming by amitosis have been observed. Spherical cells have always been observed in and outside the old layer. They are smallest inside where dividing and gradually are larger outside. The cells seem to be secretion globules of some kind that function in separating off the old epithelium and in bringing about its digestion or dissolution. Of course, small droplets may be formed during its disintegration.

In criticizing vom Rath's work Verhoeff assumes that if every epithelial cell divides to form an old and a new layer then the leucocytes must be in the inner layer. He says this is not the case because most of the leucocytes are found between the two layers, therefore regeneration as in the insects is not possible in Diplopods.

In *Euryurus* the bodies are formed in the inner layer by amitosis during and after the time when old epithelium becomes separated and thus are located in and between the two layers. They are largest between the layers. No sections have shown that the entire thickness of the mid-intestinal wall is thrown off, in *Euryurus*, and a new layer regenerated from primary leucocytes during moulting, as Verhoeff appears to claim is the case in *Polydesmidæ* and *Iulidæ*. Possibly Verhoeff's supposed leucocytes are similar to the small cells budded off in *Euryurus* from the epithelium and the latter is regenerated from primitive epithelial cells, and not from primary leucocytes. In *Euryurus*, digestive cells are rapidly used up during digestion and consequently during the feeding condition are being replaced from time to time from primitive epithelial cells. Verhoeff (1914) in his work on *Polydesmus* observed mid-intestinal transformations and found cells in all stages of development between the compressed and tongue-formed cells. It seems that he has made wrong interpretations in a number of cases. His observations are in favor of epithelium being replaced by primitive epithelial cells.

In *Euryurus* there is an exceedingly large formation of the bodies in animals which have just shed their old exoskeleton and the new chitin is still as soft as rubber. These animals are easily sectioned or dissected.

Sections showed that the spheres are not tremendously abundant until the animals are ready to shed their old skin. The spheres are of various sizes, without clearly defined nuclei if present at all. Most of them are single but many are in clusters.

Shortly after the old exoskeleton is shed the recently moulted specimen starts consuming it unless disturbed. In some cases all of the old chitin is consumed. When the first exoskeletal piece is swallowed there starts a new period of important changes in the mid-intestine.

In *Euryurus* during a part of the moulting period the mid-intestine is closed in front and behind. This reopens when ecdysis is complete, but is an obstruction to the first piece of exoskeleton. This obstruction is overcome more readily as the new mid-intestinal cuticula is formed, which separates it from the new epithelium. The exoskeletal pieces pass through the oesophagus and, in the mid-intestine, push the loosened container posteriorly.

In a specimen of *Euryurus* which had eaten about one-half of its old exoskeleton, this container was pushed back to the rear half of the mid-intestine.

Verhoeff has made similar observations in *Julidæ* and *Polydesmus*. He describes what he calls a white body and a yellow body with a yellow layer which corresponds probably to the old epithelium judging from his criticism of vom Rath's work. The yellow body described by Verhoeff in "Die Diplopoden Deutschlands" Fig. 44, page 603 corresponds to the central portion of the lumen inside the old epithelial ring in *Euryurus*, and the white body that space between the cuticula and the old epithelium. This latter space is filled, in *Euryurus*, with spherical bodies of various sizes.

Verhoeff (1914) described, in the diminishing white body, leucocytes

varying much in shape and position, with larger nucleated ones between smaller non-nucleated ones.

The yellow body is described by Verhoeff as being composed of numberless leucocytes and full of fluid. In *Euryurus* very few bodies were usually observed in the central part of the lumen inside the old epithelial layer. The largest spheres were in large masses outside the inner layer. Smaller ones were scattered or in rows through the epithelium and dividing by amitosis inside cells, indicating their functioning in its dissolution and digestion. Perhaps true digestive cells from (H) shown in Plate II, Fig. 3 digest some or all the bodies formed from the inner layer.

The epithelium of *Euryurus* soon after ecdysis assumes a typical feeding condition, as the cells are elongated and over them collect numerous round, small digestive globules which Verhoeff says are forerunners of the new primary leucocytes from which the epithelium is formed.

The reason Verhoeff gives for the disintegration of the white body is that the larger leucocytes ingest the smaller ones and at the end of this process the yellow body tube is pushed into the lower intestine.

The old epithelial cells (yellow layer of Verhoeff) seem to serve as nourishment for the new cells in *Euryurus*. These new cells start to form and function shortly before the shedding of the exoskeleton judging from numerous slides and dissections showing the spheres or secretion globules in abundance at this time and in greater quantities after the shedding and eating of the old chitin.

In a specimen of *Euryurus* which had almost totally ingested its exoskeleton the front part of the mid-intestine did not contain pieces of the exoskeleton in the cuticular tube. The epithelial cells were rod or tongue shaped and cells in various stages of development were found between them.

In Plate II, Fig. 3, the epithelial cells are very compact. At this stage after the ingesting of the exoskeleton the cells were less compact.

There were fewer of the cells formed from the inner layer in the lower half of the mid-intestine. The anterior two-thirds of the hind-intestine contained a number of exoskeletal pieces. Gregarines were found in the hind-intestine during this period. Before moulting they are found in the mid-intestine. Some parasites may thus be eliminated during moulting.

The Transition From the Mid-Intestine to the Hind-Intestine and a Discussion of the Hind-Intestine.

The hind-intestine is set aside from the mid-intestine by a fold of tissue (RF) which may be compared with the pyloric valve of insects. Possibly it is not a true valve in the sense that it closes the tract at this point but it is a fold of tissue marking the transition from the mid-intestine to the hind-intestine. (Plate I, Fig. 6 and Plate III, Fig. 4 and 4-C).

Sections from several different specimens showed the form of the folds to vary to some extent, but the general form is shown in Plate I, Fig. 6.

The transition from the rod-shaped epithelial cells of the mid-intestine to the epithelium of the hind-intestine is shown. The epithelium of the latter soon becomes lower. The chitinous intima first appeared at the beginning of the anterior face of the fold. Numerous small longitudinal folds and depressions were noticeable over the fold but posteriorly these were much larger. The epithelial cells are elongate and rather regular. In some sections considerable striated longitudinal Muscle was evident, and fibers of longitudinal muscle extend into the fold. The cuticular striated border extends from behind the fore-intestine for a certain distance into the hind-intestine.

Verhoeff (1910-1915) designated a second cuticula which he called "Einsatzrohr." He shows no drawing of it. Nothing similar has been observed in *Euryurus* nor by Randow (1924) in *Julidæ* or Effenberger (1909) in *Polydesmus*.

Both primary and secondary intimas are clearly evident. No spines were observed on the primary intima.

The epithelium is continuous from the mid-intestine to the hind-intestine. The digestive epithelial cells cease, as one might expect, at the point of the beginning of the fold or the valve and the point where the intima of the hind-intestine begins. At the beginning of the fold the epithelium was distinctly different from that of the mid-intestine. The cells were elongate and rather regular. The basement membrane appeared to be continuous from the mid-intestine to the hind-intestine. The circular muscles appear to be continuous from the mid-intestine to the hind-intestine. They are more numerous in the hind-intestine. With the beginning of the fold there appears a heavy set of longitudinal muscles in contrast to the scattered outer longitudinal muscles of the mid-intestine.

There is just one set of longitudinal muscles in the hind-intestine. They are thicker in the region of the valve and not a thin continuous layer from the mid-intestine to the hind-intestine. Posterior to the fold the longitudinal muscles were evident as a thin incomplete layer.

The histological structure of the region a little anterior to the entrance of the Malpighian tubules is shown in Plate I, Fig. 7. Both primary and secondary intimas are present. The former is much thicker than the latter and is almost transparent and has spines projecting posteriorly for a short stretch of the canal. The groove in which each Malpighian tubule has its outlet has been previously described for *Polydesmidæ* and *Julidæ*. This groove (UC) just anterior to the entrances of the Malpighian tubules is shown for *Euryurus* in the same figure. It varies from previous descriptions for either *Polydesmidæ* or *Julidæ*.

The epithelial cells appear as elongate areas which remain almost clear and with some vacuole-like spaces after staining with Harris's haemotoxylin and eosin. The basement membrane is clearly evident and the nuclei are near it.

The circular muscles are confined to an area between the epithelium and the incomplete layer of longitudinal muscles. The circular muscle layer becomes gradually thicker.

The sphincter-like constriction, a condition observed a short distance

posterior to the entrance of the Malpighian tubules is shown in Plate I, Figs. 9 and 10 and Plate II, Fig. 5. The details of structure can best be seen in Plate I, Fig. 10. The epithelial cells are smaller than in the preceding region. Small spherical light spaces or tracheoles surrounded by darkly stained outer borders were observed, indicate as (TR). A primary intima and a basement membrance were observed. The layer of circular muscles is thick and external to it are somewhat scattered longitudinal muscles.

Nothing was found comparable to the intestinal valve in the intestinal tracts of insects. A longitudinal section through a portion of the hind-intestine characterized by minute dark brown papillæ-like structures or folds (FC) is shown in Plate I, Fig. 15. A cross section is shown in Plate I, Fig. 11. Thin primary and secondary intimas appear to be present. The epithelial cells are somewhat elongated and regular and many are characterized by lightly stained areas. The circular muscle layer is much thinner and a few scattered longitudinal muscles are present.

The fold chamber narrows and the pre-anal constriction (PAC) is the next region observed. Randow (1924) described six longitudinal folds and smaller folds in between for *Julidæ*. The epithelium is lower in a region posterior to the fold chamber (FC) and gradually increases in height in the pre-anal constriction and continues to the rectum.

In *Eurvurus* the pre-anal constriction is characterized by an increase in the number of the circular and longitudinal muscle layers.

Rectum.—The intima of the rectum has folds as shown in Plate I, Fig. 12. These almost close the lumen of the gut. From Plate I, Fig. 3, its detailed structure can be deduced. The intima is distinct and slightly roughened but no spines were observed. The epithelial cells are elongate and rather regular, in comparison with low cells described in *Julidæ*. Longitudinal muscles extend to near the rectum. Circular muscles only are found in the region of the rectum.

Malpighian Tubules.

Two long and thread-like Malpighian tubules are present, attached to the alimentary canal slightly posterior to the point of transition from the mid- to the hind-intestine. The tubes pass cephalad, one on either side of the intestine, and are characterized by convolutions. They end blindly in the body cavity, attached to tracheæ. The blind ends are smaller than those attached.

Histologically, it was found that the intima is thin and irregular. (Plate I, Fig. 7). The epithelium consists of rod-shaped cells with darkly stained nuclei which make up the greater part of the wall. A basement membrane is present and muscular layers absent.

Studies on Internal Anatomy in Addition to Those on the Alimentary Canal.

Glands.

The glands of *Polydesmus* have been studied by Effenberger (1909), Verhoeff (1910-1915) and Attems (1926).

Those of *Iulus* have been studied by Plateau (1878), Silvestri (1902), Rossi (1902), Krug (1906), Wernitzsch (1910), Verhoeff (1910-1915) and Attems (1926).

Effenberger (1909) has a good review of the literature on glands of *Iulidæ*. He reported many similarities between the glands of *Iulidæ* and *Polydesmus complanatus*.

The pair of tubular glands of *Euryurus* have the outlets of the ducts the same as in *Iulus* and *Polydesmus* but the glands show a different structure than previously described. (Plate II, Fig. 8). Effenberger (1909) in his Figure 9, on page 569 shows the gnathochilarium with the ducts of the tubular glands. The ducts run between the stipites gnathochilarii and the lamella linguales or according to vom Rath, using Latzel's terminology, between the mala gnathochilarii and the lobi linguales.

Three "traubigen Drusen" or grape-like glands were observed in *Euryurus*. Two have been reported for *Iulus* and *Polydesmus*, namely front and hind salivary glands. In *Iulus* and *Polydesmus* the lower pair of salivary glands are united to form a single glandular mass with the duct outlet between mandible and hypopharynx. In *Euryurus* they (SG) are separated and lie on each side of the oesophagus. (Plate II, Figs. 7 and 8). These are similar in *Craspedosoma* described by Wernitzsch (1910).

Plateau (1878), Rossi (1902) mistook the glands for fat bodies. Also Bruntz (1904) is mistaken regarding the true nature of the lower salivary glands as he associates them with the tubular glands.

The third "traubige Druse" present in *Euryurus* is the "vordere Speicheldruse" or "Kopfdruse," or head gland, as it may be called due to its position and has been described in *Iulus* and *Polydesmus*. It lies in the head over and in front of the brain, which is above the mouth opening. The ducts have their outlets about in the mid line of the dorsal part of the mouth.

Rectal glands or "Afterdruse" in females and "Saftdrusen" or odoriferous glands are described for *Polydesmus* by Effenberger (1909). They are essentially the same in *Euryurus*. The distribution of the repugnatorial pores was described by the writer (1927).

Musculature.

1. *Body.*—The body musculature of *Euryurus* appears to be rather simple. Muscles in the right half of a body segment are shown in Plate III, Fig. 6. In each double segment three paired sets of muscle are found, namely, two dorsolateral, longitudinal bands (DMCL) from the intercostal ridge (AC) of one segment to that of the next; a pair of lateral muscles on each side (LMCL); and a pair of slender ventral muscles (VMCL).

2. *Leg.*—The segments have been numbered I to VII. (Plate III, Fig. 7). They correspond with the segments of the insect and chilopod leg, as given in a paper (p. 93) by Snodgrass (1927). The number holds almost without exception (i.e., the number of segments with muscles) in all the Arthropod groups, but the nature of the articulations and the musculature differs.

Insects, Chilopods, and Diplopods lack a levator of the dactylopodite, or claw. Crustacea and Arachnids have both levator and depressor muscles of the dactylopodite, or claw-bearing segment. The musculature of the left leg of *Euryurus*, as determined from an anterior view, is as follows:

A. Promotor of I (Coxa).
B. Remotor of I.
C. Levator of II.
D. Anterior depressor of II.
E. Posterior depressor of II.
F. Levator of III.
G. Depressor of III.
H. Levator of IV.
I. Depressor of IV.
J. Levator of V (posterior).
K. Depressor of V (anterior).
L. Depressor of VI.
M. Depressor of VII (dactylopodite).

3. *Mandible.*—This is complicated and difficult to study in *Euryurus*. The large local millipede *Spirobolus marginatus* was also studied because it is much easier to work with, due to its size and flexible body wall. Snodgrass has studied a large *Julid* from Siam. Thus, comparisons of the mandibular musculature of three forms have been made. It is believed that this musculature is essentially the same. Plate III, Fig. 5, is a drawing of the outer view of the left mandible of *Euryurus*. Figure 5-A is a dorsal view of the left mandible of a large *Julid* from Siam (after Snodgrass).

The mandible (MD) consists of two basal plates inserted into the head wall, and a distal, movable functional mandible. The basal plates have three muscles: (1) a large dumb-bell shaped muscle arising in the hollow of the basal plates on each side and continuous through the head by a thick, median transverse tendon. This muscle is lacking in Chilopods and insects but is characteristic of the more generalized Crustaces, including *Apus*. From the first basal plate a large muscle (2) goes to the bar at the sides of the mouth (suspensorium of hypopharynx). This muscle, according to Snodgrass, is present at least in *Machilis* and some Orthoptera. The third muscle (3) is a retractor, or promoter, of basal plate arising on the back of the head. The movable part of the mandible has a small adductor (4), in figure 5-A, going to the basal plate, and a large adductor (5) to the posterior dorsal wall of the head. Abductor muscles were not found and the mechanism by which the mandibles are opened is not known. The mandibular muscles appear to comprise crustacean and insect muscles and no account of them has been found.

The Nervous System.

The previous workers on this system in Diplopods are Newport (1843), Rossi (1901), Verhoeff (1910-1915) and Attems (1926).

The central nervous system of *Euryurus* consists of a brain or cerebral ganglion, suboesophageal ganglion and a ventral nerve cord with ganglia and nerves.

The brain of *Euryurus* consists of two main lobes separated by a slightly constricted area. (Plate III, Fig. 3). In the side view diagram, of course, this area does not show.

Antennal nerves are present. Optic nerves are absent, there being externally no organs of vision. The cerebral ganglia are connected to the sub-oesophageal ganglion (SG) by a circum-oesophageal con-

nection (CC). A single pair of legs is found on the first, third, and fourth segments of all the stages, and the second trunk segment lacks limbs in every case in *Euryurus*. A single ganglion (G) and two pairs of nerves (LN), (DLN) were found in the above-mentioned trunk segments.

The fifth trunk segment, as shown in the diagram, and all the succeeding trunk segments except the anal segment have two pairs of limbs. The gonopods of the male are modified from the eighth pair of legs on the seventh body segment. Two ganglia and three pairs of principal nerves were found in these segments. One pair of nerves runs dorsally, and the other two pairs run ventrally, each supplying a pair of legs.

The nerve cord is double and separated by more or less distinct strands with ganglionic swellings in each segment, which are connected by cross commissures.

In their following course both strands fuse to a greater or lesser extent into an uneven branch which is surrounded by the perineural sinus. (PNS) shown in Plate II, Fig. 7. The dorsal part of the branch is surrounded by the supraneural septum, its sides by the slanting muscles of the leg and ventrally by epithelium. The development of the supraneural septum has not been observed yet. The nerve cord rests upon a network of fat cells, part of which later are located between the epithelium and nerve cord when the cord is separate from the epithelium. Upon the ventral surface of the supraneural septum are found phagocytic organs (Bruntz 1906) and upon the dorsal are nephrocytes.

Rossi (1901) states that the ventral nerve cord of *Julus terrestris* is without ganglia, commissures and connections. He describes four pairs of nerves for each movable segment.

Newport (1843) describes in detail and illustrates in his Plate XI, Fig. 6, the central nervous system of *Polydesmus complanatus*. He states that the ganglia of the first two pairs of legs have united with the first suboesophageal ganglion. In *Euryurus* this was not the case as a single ganglion and two pairs of nerves were found in the first, third and fourth trunk segments.

Otherwise conditions in *Euryurus* are comparable to those described for *Polydesmus*.

The Tracheal System.

Many investigations have been made on the tracheal system in Diplopods. Rossi (1902) gives a detailed historical review of previous work. Wernitzsch (1910) adds additional references up to the time of his observations. He compares the tracheal system of *Craspedosoma* with that of other Diplopods (*Heteroporatia*, *Glomeris*, *Polydesmus*, *Iulus* . . .). More recent work is as follows: Verhoeff (1910-1915), Attems (1926).

Wernitzsch (1910) states that the tracheal system of Diplopods is of especial importance because it connects primitive conditions as found in Peripatus with the more complicated conditions in Chilopods and insects. The very fine unbranched tracheæ originating out of the tracheal pockets are similar to those of Peripatus and the tracheal

pockets are homologous to the ectoderm tube of Peripatus (Ziegler 1907). In many Diplopods, for example *Glomeris*, the trachea are similar to those of insects (Voges 1878).

The tracheal system of *Polydesmidæ* is considered in brief by Attems (1927) and in greater detail by Effenberger (1907) and Verhoeff (1910-1915). Verhoeff disagrees in certain points with Effenberger.

The writer has not worked out the complete tracheal system of *Euryurus*, nor checked contradictory points, however, a few observations follow, all of which are similar, in general, to those of others made on different *Polydesmidæ*. An adult *Euryurus* has twenty trunk segments. One tracheal system consists of a stigma, tracheal pouch and tracheæ and tracheoles. Stigmata were not found in the nineteenth and anal segments nor in the first, second and third segments.

One large tracheal bundle leaves a large tracheal pocket on each side of the anterior part of the sternite of the fourth segment. Each large bundle goes to the side of the head. A smaller bundle leaves each side of the anterior pocket of the fifth sternite. These latter bundles run anteriorly under the larger bundles and converge towards the mid-line of the head. Thus these bundles run anteriorly and supply the anterior segments and the head region.

In *Polydesmus* and *Craspedosoma* two pairs of longitudinal bundles run to the head region.

All investigators except Visart (1894) state that the tracheæ never bifurcate nor anastomose. Visart erroneously mentions and illustrates some tracheæ branching in the intestine of *Julus*.

The Reproductive Systems.

1. *Female.*—On the dorsal wall of the ovarial sack in *Euryurus*, running parallel on either side of the mid-line are the ovaries (EB). (Plate III, Fig. 1-A). These ovaries are covered with numerous developing ova (DO) and are enveloped by a single very delicate, transparent covering. This covering or ovarial sack has the form of a tube pressed together in a dorso-ventral direction and is located ventral to the intestinal tract and dorsal to the nerve cord.

When the eggs are mature, they become separated from the ovaries. The ovarian sac becomes much distended and gradually the ova reach the oviduct. The mutual ovarian sac terminates in a single oviduct (O) which soon bifurcates. Each oviduct branch curves laterally, posteriorly and internally (Plate III, Fig. 1-B) and connects with a vulva.

The vulvæ are attached to the second pair of legs. (Plate III, Fig. 1-B). Each vulva is composed of the opening of an oviduct, glands, and muscles. The vulvæ usually, unless the animals are copulating or ovipositing, lie in depressions surrounded by the sternite. The proximal end of each oviduct is situated on the bottom of a vulva and enters a chamber which opens to the outside. When the vulvæ are everted, the proximal end is outermost, which is most advantageous for oviposition and copulation.

The bursa makes up most of a vulva and is located behind the opening of the oviduct. The simplest operculum (OE) is in front of

the oviduct opening. The bursa is composed of a smooth, more or less depressed zone which is called "Cimier" by French writers. It appears similar to the valves of a mussel. The middle part of the "Cimier" is depressed trough-like and forms a seminal receptacle. By older authors (Fabre, vom Rath . . .) this was mistaken for a gland. In the front part of the receptacle are real glands which were previously overlooked. According to Fabre, *Polydesmus* has no seminal receptacle but Effenberger disagrees. The front rims of the valves and the posterior rims of the operculum, between which lies the oviduct opening, are connected by chitin clasps.

The vulvæ have the form of a compressed sphere and the valves and the operculum have bristles. The bristles on the valves are found on the side towards the median crest. Strong "teeth" are present. The seminal receptacle has the form of a coiled blind sac (SR). On the distal end it is bubble-shaped. Attems (1926) mentioned its lumen being filled with numberless spermatozoa in *Polydesmus*. The bottom channel piece (Kehlstuck) is to a lesser or greater extent loose from the valves. Attems (1926) described the large double-lobed bursa glands found in the front end of the receptacle and smaller gland masses, the glands of the Kehlstuck and vulvular glands.

2. *Male.*—The reproductive system of the male is formed of two long tubes united frequently with cross connections (TC) which makes it resemble a ladder. (Plate III, Fig. 2-A). The vasa deferentia start in the seventh segment and run forward with regular anastomoses to the paired openings (VD) found on projections located on the coxal joints of the second pair of legs. (Plate III, Fig. 2-B).

Fabre (1855) reported for *Polydesmus complanatus* that transverse connections disappear at about the seventh segment. Effenberger (1909) describes the vasa deferentia starting in the seventh segment and running anteriorly to the fourth segment and uniting. They go united for a short distance, then separate in the lower section of the third segment and each branch goes to its outlet in the coxal joint of the second pair of legs.

The second pair of legs is attached to the third trunk segment. The vulvæ of the female are found in a somewhat similar position attached near the base of the second pair of legs. The "ladder" commences in the next to last segment and the tubes open on projections as previously mentioned. The number of cross connections has varied some in specimens studied. Twenty-seven are shown in Plate III, Fig. 2-A. Fabre observed sometimes 13, sometimes 14. In *Euryurus*, the testicular follicles (T) usually appear in the seventh or eighth trunk segment and continue to the next to the last segment.

Effenberger states that for *Polydesmus* the spermatozoa are small, round and not free moving cells.

The seventh segment is the important one in copulation. Its first pair of legs are transformed (described by the writer, 1927) into gonopods.

Effenberger (1909) states that the internal branch of the gonopods of *Polydesmus* contains a bubble which must be filled with spermatozoa before copulation. Fabre (1855) has described in detail the filling of

the bubbles with spermatozoa. He states that before copulation the male lifts up the upper part of the body and coils S-formed, so that the third trunk segment approximates the seventh. He also observed a sperm droplet come out of each opening of the vasa deferentia and taken up by the chitin brushes which are found on the internal branches. He further states that there is no doubt that the droplets reach the bubbles through the opening (seminal receptacle) in the middle of the hair fringe.

Many male specimens of *Euryurus* have been observed coiling S-formed but the sperm droplets have not been observed coming out of the openings of the vasa deferentia and being taken up by the gonopods.

Circulatory System.

This is not as well known in the Diplopods as in the Chilopods. Rossi (1902) reviews the work on Chilopods and Diplopods in a historical note. There are a number of contradictory points in regard to the intimate structure of the heart. Rossi recorded his observations concerning several contradictory points. The most recent work is by Verhoeff (1910-1915) and Attems (1926).

The heart (HT) of *Euryurus* lies between the dorsal epithelium and the intestine. (Plate II, Fig. 7). Its walls from outside to inside are composed of circular muscle strands, a structureless cuticle or intima, adventitious cells, and a pericardial membrane. The heart appears wave-like in longitudinal sections. Its posterior end is blind while anteriorly it opens in a short aorta. In each double segment there are two ostia, two transverse vessels with short open branches, having their outlets ventral in contractile canals. These canals are lacunæ bordered dorsally by the wall of the perineural ainus and ventrally have their own walls consisting of transverse muscle fibers.

Newport (1843), in regard to ostia, does not decide whether he is dealing with simple openings or with terminations of delicate veins. He is inclined towards the latter opinion. No venous system was observed in *Euryurus* nor did Rossi find one in *Julus*.

The research upon which this report is based was carried on chiefly at The Ohio State University during a period of two years, (1925–1927). Some observations were made at the Franz Theodore Stone Laboratory, Put-in-Bay, Ohio, during the summers of 1926 and 1927; and at the Detroit College of Medicine and Surgery, Detroit, Michigan, (1927–1930).

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EXPLANATION OF PLATE I.

(Drawings).

Fig. 1. Cross-section of oesophagus. PI.—Primary intima; SI.—Secondary intima. LM.—Longitudinal muscle. CM.—Circular muscle. E.—Epithelium. Magnification=413×.

Fig. 2. Section "A" of Fig. 1 enlarged. BM.—Basement Membrane. Magnification=825×.

Fig. 3. Longitudinal section through oesophageal valve. Mid. Int.—Mid-intestine. I. L. M.—Inner longitudinal muscle. O. L. M.—Outer longitudinal muscle. H.—Cover layer. A.—Annulus. P.—Process.

Fig. 4. Cross-section of mid-intestine of feeding animal. C. S. B.—Cuticular striated border.

Fig. 5. Section of Fig. 4 enlarged. T. R.—Tracheole. Magnification=825×.

Fig. 6. Longitudinal section through ring fold. H. I.—Hind-intestine. M. I.—Mid-intestine.

Fig. 7. Cross-section of intestine, shortly anterior to entrance of Malpighian tubules. U. C.—Urine chamber. Mpg. T.—Malpighian tubule. Magnification=825×.

Fig. 8. Cross-section through intestine where Malpighian tubules enter.

Fig. 9. Cross-section of constricted region just posterior to the entrance of Malpighian tubules. Magnification=413×.

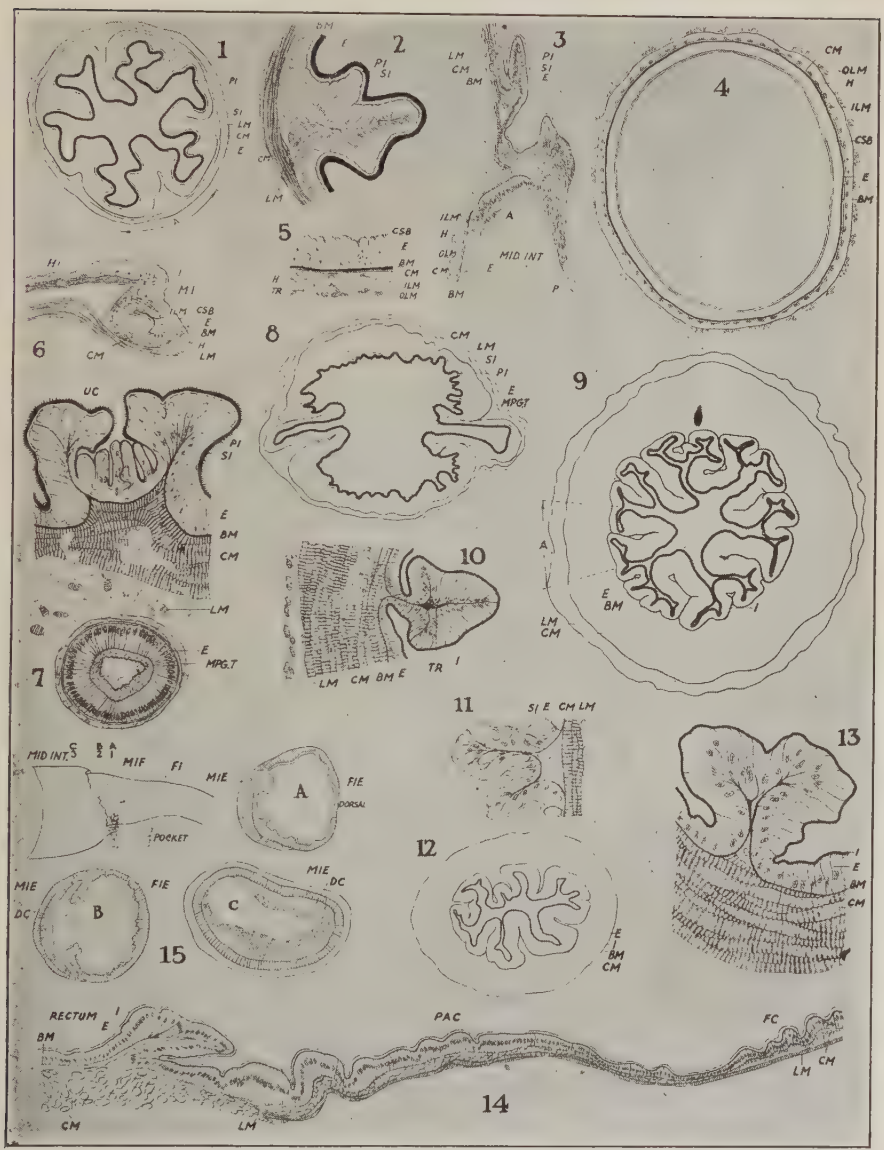
Fig. 10. Section "A" of Fig. 9 enlarged. Magnification=825×.

Fig. 11. Cross-section through fold chamber. Magnification=825×.

Fig. 12. Cross-section through rectum.

Fig. 13. Section of Fig. 12 enlarged. Magnification=825×.

Fig. 14. Longitudinal section through fold chamber, preanal constriction and rectum. F. C.—Fold chamber. P. A. C.—Pre-anal constriction.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EXPLANATION OF PLATE II.

(Photographs).

Fig. 1. Cross-section of oesophagus.

Fig. 2. Cross-section of mid-intestine of feeding animal.

Fig. 3. Cross-section of mid-intestine of moulting animal. D. C.—Cells formed in AE. A. E.—Old epithelium.

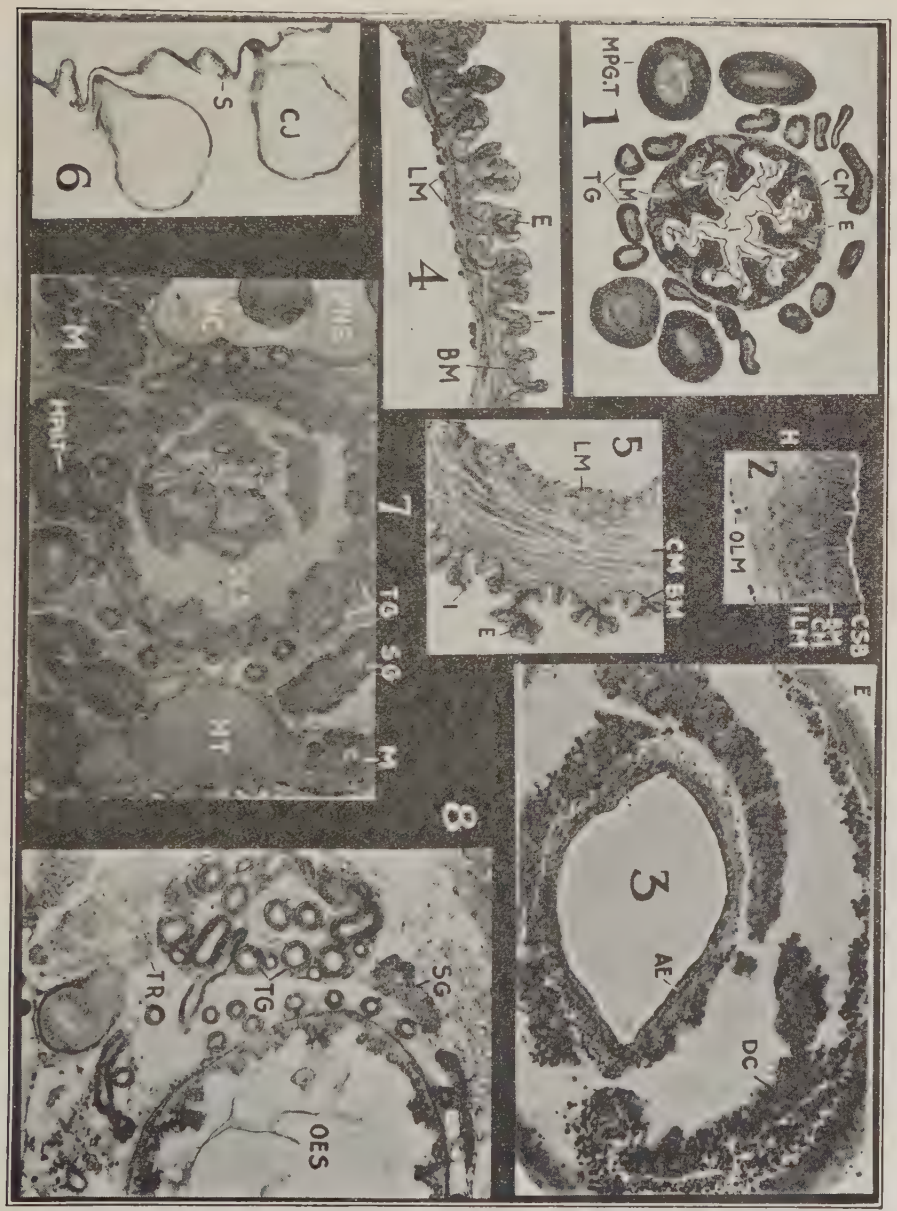
Fig. 4. Cross-section through fold chamber.

Fig. 5. Cross-section of constricted region just posterior to the entrance of Malpighian tubules.

Fig. 6. Longitudinal section through stigma and coxal joints of a segment with two pairs of legs. S.—Stigma. C. J.—Coxal joints.

Fig. 7. Cross-section through body in region of oesophagus to show relation of parts. OES.—Oesophagus. T. G.—Tubular glands. S. G.—Salivary glands. M.—Muscle. H. T.—Heart. N. C.—Nerve cord. P. N. S.—Perineural sinus.

Fig. 8. Cross-section through another portion of oesophagus, tubular gland, tracheal bundle, etc.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EXPLANATION OF PLATE III.

(Drawings and Photographs).

Fig. 1. Ventral view of adult female *Euryurus*.
Fig. 1-A. Female reproductive system.
Fig. 1-B. Second pair of legs with vulvæ and oviducts.
Fig. 2. Ventral view of adult male *Euryurus*.
Fig. 2-A. Male reproductive system.
Fig. 2-B. Second pair of legs and openings of vasa deferentia of male.
Fig. 3. Diagram showing side view of nervous system in head region and from segments 1–5, inclusive.
Fig. 4. Dorsal view of adult alimentary tract.
Fig. 4-A. Lower lip or gnathochilarium. (Labeled after Effenberger).
Fig. 4-B. Anal segment with anal plates and anal scale.
Fig. 4-C. View of portions of the inner wall of the intestine.
Fig. 5. Outer view of left mandible.
Fig. 5-A. Dorsal view of right mandible of a *Julid* from Siam. (After Snodgrass).
Fig. 6. Muscles in right half of body segment.
Fig. 7. Anterior view of left leg.

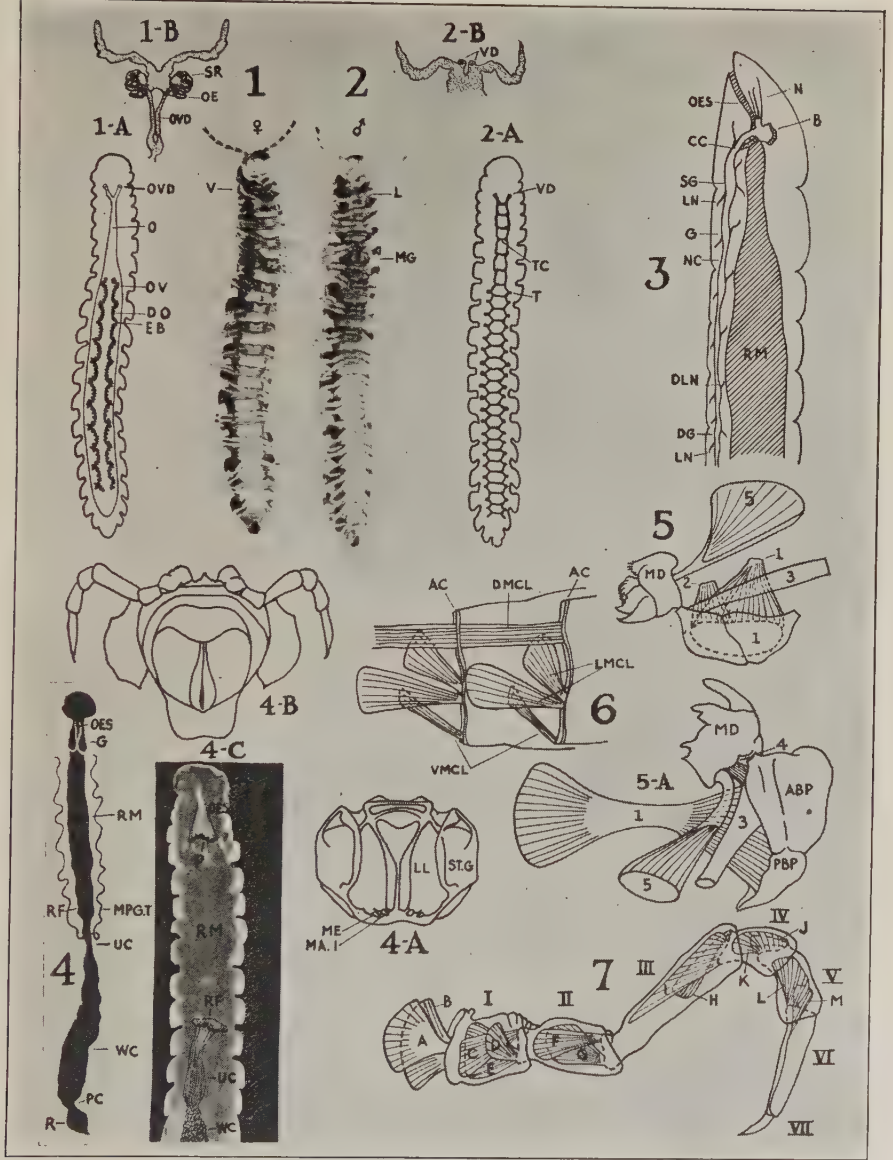
Details in Fig. 5.

1, Transverse adductor of basal mandibular plates. 2, Muscle from hypopharyngeal support to anterior basal plate of mandible (ventral to 1 in Figure 5-A). 3, Muscle from dorsal edge of mandibular plate to posterior rim of head. 4, Small adductor from mandible to mandibular plate. (Not seen in Euryurus). 5, Adductor of mandible arising on posterior dorsal wall of head.

ABP, Anterior basal plate of mandible. PBP, Posterior basal plate of mandible.

Abbreviations Used in the Figures—Plate III.

SR—Seminal receptacle.
OE—Operculum.
OVD—Oviduct.
EB or OB—Ovary.
DO—Developing ova.
V—Vulvæ.
L—Second pair of legs.
VD—Openings of vasa deferentia.
TC—Transverse connections.
T—Testicular follicles.
MG—Male gonopods.
OES—Oesophagus.
N—Nerves.
B—Cerebral ganglia.
CC—Circumeosophageal connectives.
SG—Sub-oesophageal ganglion.
LN—Lateral nerve.
G—Ganglion in Fig. 3.
NC—Nerve cord.
DLN—Dorsal lateral nerve.
DG—Double ganglion in double segment.
RM—Mid-intestine.
G—Glands in Fig. 4.
MPGT—Malpighian tubule.
RF—Pyloric valve.
UC—Urinary chamber.
WC—Fold or wrinkled chamber.
PC—Pre-anal constriction.
R—Rectum.
LL—Lamellæ linguales.
STG—Stipes gnathochilarii (Stammteil).
ME—Mala exterior (ausere Lade).
MAI—Mala interior (innere Lade).
AC—Antecostal ridge.
DMCL—Dorso-lateral longitudinal bands.
LMCL—Lateral muscles.
VMCL—Ventral muscles.
MD—Mandible.
I–VII—Divisions of leg.
A—Promotor of I (coxa).
B—Remotor of I.
C—Levator of II.
D—Anterior depressor of II.
E—Posterior depressor of II.
F—Levator of III.
G—Depressor of III.
H—Levator of IV.
I—Depressor of IV.
J—Levator of V (posterior).
K—Depressor of V (anterior).
L—Depressor of VI.
M—Depressor of VII (dactylopodite).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THE INFLUENCE OF CLIMATE ON HUMAN ORGANISM AS EVIDENCED BY THE DEATH RATE FROM CERTAIN DISEASES, AND BY CONCEPTION RATE.*

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Little effort has ever been made to ascertain in any detail the biological influences which climate may exert upon the human race. Certain differences between people of different countries have been recognized and classed as racial or environmental in origin, but no serious effort has ever been made to see how much is due to the climatic factor alone. Huntington (1) has presented perhaps the most interesting observations and theories along these lines, showing climate to be very important in the development or regression of peoples. It still remains, however, to establish the more exact manner in which man is thus influenced.

During a two years' sojourn in north China, the writer became much interested in the possible physiological effects of the intense and constant moist heat of their tropical monsoon summer period, which extends practically to the Arctic circle. The people of China, from Canton in the south to Mukden in the north, have been found to consume oxygen at a rate about 10% less than that of people of Europe and northern United States, their blood pressure is about 10% lower, and various other measurements show a level of physical activity distinctly below our accepted western standards. Westerners staying two years or more in China often suffer a distinct fall in blood pressure, while Chinese coming to Europe or America show a rise in pressure and energy expenditure.

In addition to these physiological differences which seem to result from prolonged residence in the Orient, it was observed that the incidence of certain metabolic diseases, such as diabetes mellitus, pernicious anemia and exophthalmic goiter, was very low among the natives, and of mild form when present. Arteriosclerosis with hypertension was also very infrequent, which

*Presented at the meeting of the Ohio Academy of Science, April 18, 1930.

would fit in well with the general low level of blood pressure. In other words the very diseases which are increasing at such an alarming rate in America, are very mild or non-existent in the Orient. This raised the question as to what factors could possibly be responsible for such differences.

As a starting point for a study of this question, I collected statistics on the death rates for various diseases in all possible countries, and in the different states of this country. Recognizing that mortality statistics can be no more reliable than is the ability of the physician signing the death report, still I feel that they offer at present the best information obtainable over any considerable portion of the world. The information obtained has indicated a very definite geographic, or climatic, influence at work on the mortality from these diseases.

Diabetes Mellitus.

Diabetes Mellitus, for instance has a mean death rate of 9.9 per 100,000 population in 11 southern states for 1920, 1925, and 1926, while the northern states range upward to the high point of 22.1 for New England. The cities show similar differences, ten southern cities having a rate of 14.1 diabetic deaths per 100,000 population, 20 cities through the central section from San Francisco to Baltimore with a rate of 20.4, and 26 cities farther north having a rate of 23.0. The negroes show this increasing diabetes death rate toward the north even more strikingly than does the white race. Thus the colored rate is about 4.0 in gulf states, rises to 8.2 in Virginia, 11.2 in Kentucky, 17.0 in New York, and 17.6 in Pennsylvania. In the last state named the colored rate is higher than for the white race, as is also true in Kentucky. This same difference is seen in the countries of Europe, the low rates being found south of the 50th parallel, and the high rates north. Finally, a survey of the diabetes death rate over the earth shows it to be generally low in the tropics, subtropics and Orient, and high in the cooler countries both north and south of the Equator. Australia, New Zealand and South Africa for instance have high rates such as are seen in northern Europe, northern United States and Canada.

Pernicious Anemia.

With pernicious anemia much the same distribution is found although the difference is even more striking. In the

southern states the rate is 2.1 deaths per 100,000 population while the rate in the north is 6.8, rising as high as 10.4 in Iowa. The rate throughout the tropics and orient is very low, while in the cooler countries both north and south the rate is high and was rapidly increasing up to the advent of liver therapy in 1926. Since then it has been decreasing in the countries with the high rates.

Exophthalmic Goiter.

With exophthalmic goiter the story is slightly different. Although there is the same difference between northern and southern states, with a mean rate of 4.0 in the north and 1.5 in the south, there is also found a low rate in all states bordering on the Atlantic ocean, even including Maine. On the Pacific ocean the rate is high. This same oceanic effect is found in the provinces of Canada. Further search will be made for the explanation of these findings. Over the rest of the world we find a low death rate from exophthalmic goiter in the tropics, sub-tropics and Orient, and a high rate in the cooler countries. Jamaica provides an exception worthy of note. Although located in the tropics, it has headed the list of countries with high goiter death rates for the last few years. Previous to about 1924 it had practically no deaths from exophthalmic goiter.

Addison's Disease.

Deaths from Addison's disease number only 0.1 per 100,000 population in our southern states as contrasted with 0.5 in the rest of the country. The other countries of the earth show the same climatic differences as were seen for the other diseases. Jamaica, however, again comes high in the list, quite out of its class as a tropical country.

Angina Pectoris.

The death rates for angina pectoris were taken as a rough index of the blood vessel changes and blood pressure. It was noted in China that arteriosclerosis and hypertension occur with much less frequency than in America, and that the mean blood pressure of the people is distinctly lower there. The blood pressure of foreigners going to China falls slightly after a residence of more than two years there, but rises after returning home. It was, therefore, thought that it would be of

interest to study the death rate from angina pectoris under different climatic conditions.

In our southern states its death rate is 9.8 per 100,000 population as contrasted with a northern rate of 18.6. In various countries over the earth the rate is generally low in the warmer latitudes and high in the cooler regions. Again Jamaica is high in the list of countries with high rates. It will be of great interest to ascertain what change has taken place in this island in the last 6 or 8 years that might be responsible for its high death rate from exophthalmic goiter, Addison's disease and angina pectoris. Japan and North China on the other hand, although placed well north, have truly tropical rates for all these metabolic diseases. This may perhaps be due to the tropical summers which they must endure.

Human Fertility.

In attempting to determine the effect of climate on the sex glands, recourse was had to the birth statistics in various regions. The numbers of births in each month for any locality were obtained, the months equalized to a 31 day basis, and the time of conception calculated by counting back 9 months and 10 days. The variations in the conception rate thus obtained were studied in relation to the mean monthly temperature, rainfall and relative humidity.

In the northern countries and states, where the winter temperatures are low and the mean July and August temperature does not rise above 70° F., the conception rate is low in late winter rises through April, May and June, to a summer peak, and falls gradually through the fall months. This applies, for instance, in such countries as Canada and the Netherlands, and in the state of Maine. As we go further south and the mean temperature rises above 70° F., a slight summer depression in conceptions occurs which becomes more marked the higher the mean summer temperature goes. In such cities as Charleston, South Carolina, and Tampa, where the mean temperature rises to 82° F. and 83° F. for the summer, there occurs corresponding depressions of 27% and 31% in the conception rate for the heat period.

In Japan the conception rate is exceedingly high for the three spring months from March 15th to June 15th, but then suffers a 50% reduction through the succeeding three months of summer heat and constantly high humidity. Dr. T. J.

Le Blanc obtained data on the use of houses of prostitution in Japan throughout the year, and found no reduction in this evidence of male sexual activity during the summer months. Since in Japan the male sexual activity would dominate the picture so far as frequency of intercourse is concerned, we may infer that the marked reduction in summer conceptions represents a reduction in fertility of the population. Less than 10% of the spring increase in conceptions in Japan could possibly be attributed to the spring increase in marriage rate. In Switzerland, for instance, there is a second marriage peak in the fall which is accompanied by no increase in the conception rate. Therefore fluctuations in the monthly marriage rate are not an important responsible factor in the conception rate changes. It would seem fairly certain, then, that we are dealing with real changes in human fertility.

It is of interest to note that, not only do mean temperatures above 70° F. depress fertility, but those below 40° F. act likewise, and around 65° F. is always found the highest conception rate for the year. Huntington, studying human efficiency in various fields of endeavor, arrived at 64° F. as the optimium temperature for maximum efficiency.

Conclusions.

In conclusion, then, it seems evident that climate does exert a distinct effect on the activity of the endocrine glands, and through them it markedly influences the death rate from the metabolic diseases. The most stimulating climates and those leading to highest human efficiency, are also those where the over-stimulative or exhaustive diseases are most prevalent and most rapidly increasing. These facts should be recognized and proper steps taken to control the high rate of metabolic breakdown in the cooler climates. The northerner living a high-pressure life should go to Florida, not in February when the climate there is most stimulating, but in mid-summer when it is most depressing to the metabolism. It would seem probable that certain portions of the human race are trying to live beyond their metabolic possibilities.

NOTE:—A more detailed consideration of the various phases of these statistics will appear in issues of the Archives of Internal Medicine.

REFERENCE.

(1) Huntington, Ellsworth, "World Power and Evolution," Yale University Press, New Haven, 1920, page 230.

PRINCIPLES OF PLANT TAXONOMY. IX.*

JOHN H. SCHAFFNER.

In the eighth paper† of the present series, a general synopsis of the Thallophyta was given, together with a diagramatic "tree" of relationships of the orders recognized. Since the fungi are of special importance and are thus often studied independently of other groups and since the true fungi evolved a distinctive type of plant body and cell constitution, the following analysis is presented as a partial explanation of the arrangement of the groups in the synopsis. Special attention has been given to the development of correct interpretations of life histories in the light of special studies on the problem of sex in plants in general as well as comparative studies of life cycles.

THE FOUR GENERAL TYPES OF FUNGI.

If we use the term Fungi to include all Thallophytes without chlorophyll, then these plants fall into at least four distinctive, fundamental groups or great phyla. The various kinds of bacteria, including the slime bacteria (Myxobacteriales), show a very profound segregation from the remaining groups and are closely associated with the blue-green algæ in the Schizophyta.

The saprophytic slime-molds constitute a very distinct phylum of their own, whose nearest relatives are probably to be found among the Rhizopoda of the animal kingdom on the one hand and among the Archemycetæ on the other, especially the Plasmodiophorales. But they are, nevertheless, so widely divergent from either of these groups that they are best considered as a distinct phylum which has evolved along its own lines from a very primitive starting point.

The two classes, Archemycetæ and Monoblepharideæ, show a decided correspondence to various groups of the great mother phylum, the Gonidiophyta consisting mostly of flagellate green algæ. They appear to be members of this group which have lost their chlorophyll. These two classes differ in various respects from the true fungi (Mycophyta). The Archemycetæ

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†Principles of Plant Taxonomy, VIII. Ohio Journal of Science 29: 289–299.

have nothing that can properly be called a mycelium. They range from forms apparently without sex, but which may nevertheless have this potentiality, to forms with well developed sexual conditions. The conjugations of the sexual forms are, however, of the more primitive and normal types of sexual fusions and not the highly specialized condition of the Mycophyta. The Monoblepharideæ are plainly a direct offshoot from the Siphonocladales of the Gonidiophyta and have the sexual processes which are typical for the higher green algæ. A *Monoblepharis* is simply a green alga that has lost its chlorophyll, in the same general sense that *Cuscuta* and *Monotropa* are Angiospermæ that have lost their chlorophyll.

The remaining chlorophylless thallophytes are the true fungi and make up the phylum Mycophyta. This phylum is characterized by its peculiar vegetative body, the mycelium, and by a specialized sexual process, the conjugation nearly always taking place between the walled sexual cells or branches. Such a process occurs only in one other group, the higher Zygophyta, with which the fungi show no close correspondence otherwise. The Mycophyta are also to be derived from the great mother group of green algæ, the Gonidiophyta. The correspondence in the original life cycle and filamentous body is very great. The normal green alga has a simple haploid sexual cycle, the only diploid nucleus being in the zygote. The true fungi have exactly this cycle at the lower levels and the higher forms have evolved a direct modification of it. There is no correspondence with any other of the higher thallophyte phyla. Neither the red or brown algæ nor the Charophyta whose life histories have been worked out have such a life cycle. The supposed correspondence of some fungi with the red algæ is entirely superficial. Fungi could not be derived from red algæ without a complete recreation of almost the entire ontogeny. Whether one derives the Mycophyta by a separate line from the green algæ or through a series of Archemycetæ is of no fundamental phyletic importance since in either case the primary derivation must be from the green-algal complex.

The Mycophyta fall immediately into two very distinct subphyla, Phycomycetæ and Mycomycetæ. The first group is cenocytic, the second has a mycelium of normal cells although cenocytic developments may be present. Now we can derive these two groups independently from the green algæ, the first

from the cenocytic Siphonocladeæ, the second from the Conferveæ. Or what is just as reasonable from the present evidence, we can say that they had a common origin as fungi, and then after being segrated from the algal line as chlorophylless plants they divided into two phyletic series in the same way as the green algæ, divided into cenocytic groups and groups which have their filaments made up of normal cells.

At the transition from green plants to typical Mycophyta the fungi were probably still isogamous or nearly so and then evolved to various degrees of heterogamy. The progress of the sexual condition was influenced by several peculiar developments which led away from the typical course of sexual evolution as it appeared in the main line of plants from the green algæ to the seed plants.

In some of the lower groups of fungi zoospores are characteristic cells of the life cycle in others and in all of the higher fungi no zoospores are in evidence. Here again we can have the choice of two alternatives in speculating on phyletic origins. For just as some green algæ in a water habitat have zoospores and some have not and the same in respect to the two great phyla of Phaeophyta and Rhodophyta, so our ancestral Mycophyta may all have had zoospores and then mutated into nonmotile forms after or at the time they took up an aerial life; or they may have developed the two types of motile and nonmotile spores and gametes before they passed from the water, if it is true that they became fungi before taking up an aerial life. It is perfectly evident that the absence of zoospores in a group is no criterion for assuming that such absence is the result of aerial conditions.

In general, the lower fungi have a loose undifferentiated condition of the mycelium while as one ascends the scale a more and more complex body is evolved, until the truly marvelous is reached in the higher Pezizales and Phallales. This complex interacting system has thus taken the same general course and direction as that which has evolved in the solid aggregates of the higher, vascular plants. But the development of complex tissue systems and organs in the fungi appears much more remarkable because the unitary interaction is accomplished through a branching system of filaments rather than in the closely packed contiguous cells of a solid tissue. Along with the development of a complex interaction and correlation system goes the development of diverse chemicals, colors and

substances, duplicating in a remarkable manner the same evolutionary movements in evidence in the higher vascular plants.

The phylogenetic movement in the rusts is in evidence not so much in the evolution of the plant body as in the complexity of the spore forms. The Teliosporæ, therefore, make up a phyletic line which advanced in a different direction from the typical Basidiomycetæ.

There are several difficult problems which come in with a consideration of the Laboulbenieæ. These plants must have segregated as a distinct phyletic line from the primitive Ascomycetæ almost from the beginning and have therefore both a peculiar fungous body (which can hardly be called a mycelium) and some very distinctive reproductive characteristics. Apparently the life cycle is the typical simple haploid sexual cycle and the slight superficial resemblances to certain features of the red algæ must be regarded like other accidental mimicries, which indicate neither phylogenetic relationships nor even a common causal basis. The development of conidia in the male reproductive branches of some Laboulbenieæ as well as in some discomycetous lichens is to be explained by the assumption of the presence of hereditary factors which give a proper functional gradient in the antheridial branch so as to throw conidium-producing heredity into activity at this point. This process does not interfere with the primary sexualization of the cells involved and thus these cells act as normal male cells in reaction with the trichogyne of the ovary. In all such cases attention must be fixed on the complex of hereditary potentialties, which are thrown into activity or latency through the development of the proper physiological states in the cells involved. The plant is not built up of "bricks and boards" but by a functional process which is induced through the interaction of the hereditary potentialities, the progress of the physiological and ontological gradients in the given parts, and the influence of the immediate environment. The old morphological speculations are largely beside the mark. When for example we cause stigmas to grow out of the tips of stamens or microsporangia to develop in the walls of an ovulary, the result does not mean that these structures were ever so associated phylogenetically but simply that we have disturbed the normal functional gradients and the normal physiological states of the cells by changing the usual environment. So also in the

evolution of a series of plants, new potentialities may appear which will produce changed functional gradients and changed physiological states in the cells at the given ontogenetic point; and thus new and somewhat different expressions from the earlier ones appear.

The origin of endogenous spermatia must be regarded as a secondary development unless it is a hold-over from a more primitive condition which is not likely. It is far more reasonable to assume a secondary conidium-like development on the order of the peculiar conidia of Thielavia where they are developed in a sheath. Whatever one may conclude as to the origin and final relationships of the Laboulbenieæ, it is far better to set them aside as a distinct class from the other Ascomycetæ. This disposal will show the very decided way in which they have digressed from the other Mycomycetæ in general and from the Ascomycetæ in particular.

THE EVOLUTION OF THE FUNGUS LIFE CYCLE.

As stated above the life cycle of the typical fungi is the simple haploid sexual cycle or some direct modification of this. (See Figs. 1 and 2.) There is no alternation of generations, the only diploid cell being the zygote. (See Fig. 3.) Some phases of the life cycle of the fungi have been discussed previously by the writer which may be considered in this connection.* The incipient ascus and incipient basidium are homologous structures and really represent the zygote in general. The basidium is the more specialized structure. This does not mean, however, that the basidium is a transformed ascus, or that it is to be derived from an ascus. Both structures have probably been derived from a simpler condition which would not properly be called either an ascus or a basidium. The septation of the basidium has taken place independently in several lines of Teliosporæ and Basidiomycetæ. Such parallel developments occur very commonly in diverse groups of higher plants and are not to be interpreted as indicating direct relationships unless the other morphological and physiological characteristics are in agreement.

The lower groups of the various series are mostly hermaphroditic (homothallic) and this condition may continue to a

*Schaffner, John H. Principles of Plant Taxonomy, III. Ohio Jour. of Sci. *26:* 294–310. 1926.—Extraordinary Sexual Phenomena in Plants. Bull. Torr. Bot. Club, *54:* 619–629. 1927.

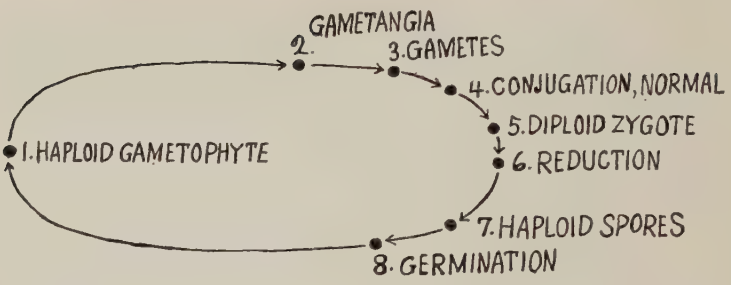

FIG. I.

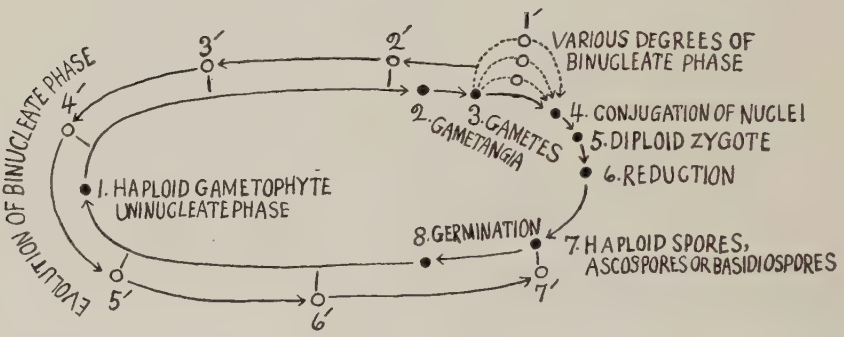

FIG. II.

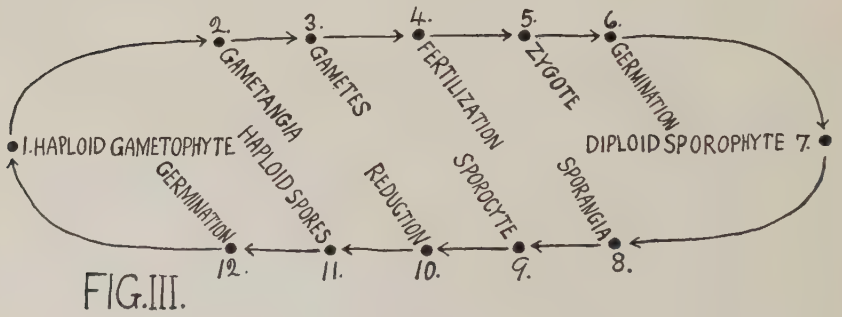

FIG. III.

EXPLANATION OF FIGS. 1, 2 AND 3.

FIG. 1. The normal simple haploid sexual life cycle.

FIG. 2. Diagrammatic representation of the evolution of a conjugate phase by modification of the simple haploid sexual life cycle of the lower fungi.

FIG. 3. The typical antithetic alternation of generations cycle which shows that there is no real alternation of generations of any kind in the fungi.

very high stage or even to the highest, as is also the case with bisporangiate flowers in the Anthophyta. As the series evolve, they usually develop species with unisexual individuals, female (+) and male (−), or heterothallism. The peculiar evolution of the binucleate phase in the highest species makes heterothallism, in the ordinary sense, impossible, since the plus (+) and minus (−) conditions are manifest only in the conjugate nuclei, and the synaptic chromosome mates. In the extreme species the entire mycelium is binucleate and the plus (+) and minus (−) states are in the inside of every cell. In addition to the remarkable development of the incomplete primary sexual states there also appears to be an evolution, in some groups, of decided physiological compatibilities and incompatibilities between various chromosome combinations, so that the ability to conjugate may involve more than the mere fact of plus and minus strains. These phenomena are comparable to the numerous physiological strains which involve the resistance and susceptibility of host plants, as in certain smuts. There have been various fantastic interpretations of the phenomena, but it is evident that the diverse types of mycelia produced with consequent incompatibilities of sex reaction do not mean that the Basidiomycetæ have an indefinite number of "sexes" but rather that the same kind of physiological conditions arise, because of the presence of specific chromosomes in the given nuclei, as those which interfere with the conjugation of sperms and eggs of diverse species of plants and animals.

The life cycle of an ordinary green alga or of a lower fungus is shown in figure 1. This, as stated, is the simple haploid sexual cycle. *Eremascus fertilis* has such a cycle except that the four haploid nuclei resulting from reduction are increased to eight by the addition of a vegetative division, giving eight ascospores instead of four which is the more common number following a reduction division. In *Coleochaete* the divisions are also multiplied after reduction. *Eremascus albus* has the same cycle and apparently the Phycomycetæ in general also. In figure 2 this simple haploid sexual cycle is indicated by the stages marked 1-2-3-4-5-6-7-8. When one passes from the Phycomycetæ to the lower Ascomycetæ, a very remarkable condition becomes evident through the intercalation of a binucleate phase between the cytoplasmic conjugation of the walled gametes and the final conjugation of the male and female nuclei to form the zygote. The first evidence of such a con-

dition evolving is the long delay in the fusion of the paired nuclei after they lie together in the fusion cytoplasm. This condition is present in some Zygomycetæ and in *Endogone lactiflua* where nuclear fusion is apparently not accomplished until the time of germination of the zygote (See Fig. 2=7-8-1-2-3-1′-4-5-6). In *Endogone pisiformis* fusion is said to occur shortly after copulation of the sexual branches. (See Figs. 1 or 2=7-8-1′-2-3-4-5-6). Some Oomycetæ also appear to have delayed nuclear fusion.

Now this condition of a partial attractive and interactive property of gametes, which for the time being falls short of complete nuclear fusion, the writer has called the incomplete or partial primary sexual state. Such states develop in the gametes of certain species of *Oedogonium* and *Bulbochaete*, where, although the original sperms (androspores) are attracted, no fusion of cells takes place for the time being but the androspores develop into dwarf males.

To gain a correct understanding of the peculiarities of sexual expression of the higher fungi, it is necessary also to take into account the various sexual states which may be present and their influence on the behaviour of the protoplast. The sexual states evident are: (1) Neutral state; (2) male and female secondary sexual states, which influence hereditary expression but do not induce attraction and fusion; (3) incomplete male and female primary sexual states, which induce attraction and in the fungi copulation of the cells involved but not a fusion of the nuclei, the nuclei nevertheless exerting an influence on each other so that they act harmoneously; and (5) complete male and female primary sexual states, which induce not only attraction but complete fusion of the nuclei, resulting in the organization of a unitary diploid nucleus; and at a later stage through the individual sexualization of the chromosomes, during the reduction division, giving rise to pairing and temporary fusion of the synaptic chromosome mates.

Now as stated above the delay of the fusion process in some of the lower fungi indicates a delay in the complete primary sexualization of the fusion nuclei. This delay turus out to be the initial stage of a remarkable orthogenetic evoln-tionary series; for the next step is the intercalation of vegetative divisions in the pair of conjugate nuclei, giving rise to the conjugate vegetative phase of the life cycle. In the lowest stages of this evolutionary movement, only a few divisions

take place, giving rise to small binucleate ascogenous hyphæ, on which the incipient asci are developed, in which, with complete primary sexualization of the conjugate nuclei, the diploid zygote nucleus is produced. This condition is present in such low Ascomycetæ as *Pyronema*, *Phyllactinia corylea*, etc., where the sexual cells or organs are slightly dimorphic. This dimorphism is due to a slight evolution of secondary sexual states which come to expression in the cells involved. After the copulation of the conjugate cells, the pair of conjugate nuclei undergo conjugate divisions in the small ascogenous hyphæ. The conjugate phase is soon ended by the formation of the hook-shaped processes at the tips of the binucleate hyphæ. This hook-shaped process must be regarded as a result of secondary sexualization of the cell concerned. The influence surrounding the male conjugate nucleus having its effect, at this stage, on the surrounding protoplasm while the cytoplasmic field surrounding the female conjugate nucleus is influenced in a different way. This differential secondary sexual condition is more marked in the higher Basidiomycetæ and is responsible for the development of clamp connections which are to be compared to the dimorphic development of the pair of gametangia in such algæ as *Vaucheria sessilis* and more especially with the end to end conjugation apparatus developed in some species of *Spirogyra*. Such similarity of morphological expression is to be looked upon as parallelism just as there are numerous parallel developments from isogamy to heterogamy or the evolution of secondary sexual states beyond the gametangia.

Not only is there an orthogenetic evolutionary advancement in the conjugate phase but there soon appears a characteristic movement, into earlier stages of the ontogeny, of the initiation of the incomplete primary sexual states or the time of determination of the conjugate phase. Thus the original conjugating cells or gametangia disappear since the secondary sexual states which arise in the new vegetative conjugating cells are apparently not intense enough in many cases to produce such dimorphism although in the higher Basidomycetæ some dimorphism does appear in connection with the development of clamp connections.

In some of the higher Ascomycetæ, as in *Humaria rutilans* and *Helvella*, the time of development of the incomplete primary sexualization is shifted backward in the ontogeny so that conjugation of the two cells takes place in the hyphæ of the hypo-

thecium. The life cycle is then approximately represented by Fig. 2=7-8-1-3′-2′-1′-4-5-6. These plants may, of course, have been in an isogamous condition when the conjugate phase began to evolve and then never got beyond this condition.

In the basidiomycetous series the development of the conjugate phase has gone farther as one would expect, from their more advanced condition in general structure and function. In the common rust, *Puccinia graminis* the uninucleate phase is developed on the barberry and ends with the aeciospores. The nature of the sexual conditions is not yet entirely cleared up but the plus and minus sexualization seems to be accomplished in contiguous cells in the base of the aecium. The nature of the pycnium is obscure, but it is not probable that it ever had anything to do directly with an antheridium phylogenetically even though it might be shown to develop male states at present. Much investigation remains to be done on the rusts before their variously complicated life cycles can be properly homologized. There are probably both homothallic and heterothallic primary mycelia present. In the smuts there is sometimes a short uninucleate phase, the binucleate phase being originated through the conjugation of sprout cells which are vegetative descendants of the basidiospores. The life cycle would then be according to the scheme of Fig 2=7-8-6′-5′-4′-3′-2′-1′-4-5-6. In the Tilletiales as in *Tilletia tritici*, the movement has proceeded further and the incomplete primary sexualization takes place in the basidiospores which then promptly conjugate and thus initiate the binucleate phase (Fig. 2=7-7′-6′-5′-4′-3′-2′-1′-4-5-6). In *Ustilago nuda* the movement has gone one step further. The four cells of the basidium (promycelium) which really represent four reduction spores or undifferentiated basidiospores develop the incomplete primary sexual states and thus initiate the binucleate phase. Now the fact that these smuts have evolved the binucleate phase to the limit is not to be taken as a criterion for placing them at the top of the taxonomic series of basidiomycetous forms. They are at the top of the conjugate series just as cycads have advanced to the extreme, diecious condition while sunflowers still have bisporangiate flowers. This condition does not place sunflowers below cycads. The general level of a species or group must be judged by the combined levels of all the evolutionary movements present.

Apparently some of the Basidiomycetæ still have a short uninucleate phase at the beginning of their life cycle. Their

cycle will then be represented by Fig. 2=7-8-6′ or 5′-4′-3′-2′-1′-4-5-6. Such a condition is apparently present in *Collybia conigena*, *Coprinus fimetarius*, etc. In species of this type cenocytic divisions may sometimes be present at first but these cenocytic developments have no direct bearing on the evolution of the conjugate phase.

In *Corticium* and apparently in many Gasteromycetæ the mature basidiospores are binucleate and subsequent divisions are of the conjugate type. The entire mycelium is therefore, binucleate. In *Secotium* according to Cunningham, each basidiospore receives one of the four reduction nuclei and the spores become binucleate promptly by division. On germination a germ tube is produced which branches abundantly, forming a septate mycelium and all the cells are binucleate. Thus the incomplete plus and minus primary sexualization is accomplished at the very beginning in two vegetative sister nuclei and conjugation of walled cells, or copulation, is entirely eliminated. There is also no more possibility for the development of a heterothallic mycellium. The evolutionary movement of incomplete primary sexualization has proceeded to the very limit. In *Secotium* the life cycle is thus as in Fig. 2= 7-7′-6′-5′-4′-3′-2′-1′-4-5-6. Apparently the life cycles of *Lycoperdon excipuliforme* and of *Cyathus*, as reported, are quite similar.

The condition in *Secotium* is only the extreme vestige of the homothallic condition. In some Basidiomycetæ heterothallic conditions are present. The sexual states are determined in the initial nucleus of the basidiospores through functional states which to some extent may coincide with the presence of differential chromosomes distributed in the reduction division. In addition there may be combinations of physiological races or physiological states depending on individual chromosomes which may give compatible and incompatible reactions in connection with the sexual states developed, as discussed above. Referring only to the development of sexual states in relation to differential chromosomes, the conjugation of basidiospores, when such takes place, might be between homothallic pairs (homothallic condition) or between heterothallic pairs (heterothallic condition). If copulation of walled cells is eliminated, the two nuclei which come to be included in the basidiospore may also be homomorphic (homothallic condition—*Secotium*) or they might possibly also be heteromorphic and thus the vestige of a heterothallic condition.

The development of numerous reaction systems is not necessarily ascribed to a complexity of hereditary units shifted in the reduction division. There may be physiological differentiation giving peculiar sexual reactions and degrees of sexual compatibility and incompatibility, just as we have bacteria with intensified or attentuated virulence, depending apparently on the environmental conditions in which the organism is growing. Or as the two dichotomous buds of a Lycopodium, although having exactly the same hereditary constitution, react differently, the one growing against the force of gravity and the other at right angles to it. Or as in the sexual incompatibility developed in many flowering plants where the differentation processes going on in certain types of hereditary constitutions result in complete self-sterility, while compatibility is shown with another individual.

The clamp connections are to be interpreted as due to secondary sexual states arising in the respective fields of influence of the plus (+) and minus (−) conjugate nuclei, at the time of each division, thus giving dimorphic expressions in cells and parts of cells comparable to the general development of sexual dimorphism in gametangia and the vegetative tissues beyond the gametangia. In this sense clamp connections can be compared directly with the hook-shaped structures in the Ascomycetæ. They do not necessarily imply any close derivation of the Basidiomycetæ from the Ascomycetæ, althought there can be no question but that Ascomycetæ and Basidiomycetæ are a monophyletic group of two more or less parallel series and that these in turn constitute a monophyletic group together with the Phycomycetæ, but not derived directly from them.

The orthogenetic evolutionary movement shown in the point of determination of the incomplete primary sexual states duplicates in a remarkable manner similar orthogenetic evolutionary movements in the time of secondary sex determination in the groups of sexual algæ, in the gametophytes of the Metathallophyta, and in the sporophytes of the heterosporous plants. In each of these series the evolution continues in a progression through the ontogeny of the individual, from determination at the end of the ontogeny to determination at the very beginning of the ontogeny when the extreme forms are reached. Such processes and relationships must be fully understood before correct phyletic taxonomies can be established.

SUPPLEMENT TO CATALOGUE OF TYPE FOSSILS IN THE GEOLOGICAL MUSEUM AT THE OHIO STATE UNIVERSITY.

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In 1924 a catalogue of the type fossils contained in the Geological Museum at the Ohio State University was published.* Since that date the collections have been increased by the addition of 106 types, and it now seems advisable to bring out this supplement to the catalogue of 1924. The plan of the supplement is the same as for the catalogue, both being patterned after the catalogue compiled by Dr. Charles Schuchert for the fossil invertebrates in the United States National Museum.†

For each entry the following information is given: (1) accession number; (2) name of species; (3) kind of type and number of specimens included in the entry; (4) formation; (5) locality; (6) author and place of publication. If the species name has been changed from that under which it was originally described, it is listed in the catalogue under both the original and the present names, with suitable cross references. Under the original name is listed the reference or references to the original description, and the cross reference is indicated by "=" the name under which the species is now known. Under the present name is listed the reference to the publication in which the change of name was made, and the cross reference is indicated by "*see*" the name under which the species was originally described. In the case where a type specimen has been described or figured under two or more names antedating the present name, a cross reference between these names is indicated by "*same as*" the other now discarded name. A few cases of this sort are listed in the original catalogue. If the generic name now used is not the same as that under which the species was originally described, the author's name is placed in parenthesis.

*Morningstar, Helen. Ohio Jour. Sci., Vol. XXIV, No. 1, pp. 31–64, 1924.
†Schuchert, Charles. U. S. Nat. Mus., Bull. 53, Pt. 1, 1905.

Of the 106 types listed in this supplement 45 are primary or basic types, and 61 are secondary or supplementary types. With the exception of two or three specimens, all this material is from the Ohio rock formations. Some entries are included which were listed in the original catalogue as *chirotypes*. Descriptions and illustrations of these species have now been published, and the proper terms for the various types are here recorded.

The terms used descriptive of the various kinds of types are the same as those used in the catalogue of 1924. The definitions of these terms are as follows:

PRIMARY TYPES.

Holotype.—A single specimen selected from the original material on which a new species is based.

Paratype.—A specimen selected in addition to the holotype which is used in preparing the original description of a new species. A species may have, therefore, both holotype and one or more paratypes.

Cotypes.—Two or more specimens used in describing and figuring a new species where no holotype has been selected.

Chirotype.—A term applied to material described in the manuscript form. After the manuscript has been published the chirotype will become either a holotype, paratype, etc.

SECONDARY TYPES.

Plesiotype.—A specimen which was not used in the original description of a new species, but which is used for a subsequent description or figure of it.

ARTIFICIAL MODLES.

Plastotype.—An artificial cast or model made directly from a primary type is called a plastotype.

FIGURED SPECIMENS.

This includes specimens which have been described and figured but to which no specific name has been assigned. They cannot be classed as real types, and such entries are marked *figured*.

MARKING OF TYPES.

To distinguish primary types in the Geological Museum at Ohio State University small red stars are glued to the specimens. For the supplementary types green stars are used. The label is also starred and on it is recorded the kind of type and the reference to the description.

The total number of entries included in the catalogue of 1924 and the present supplement is 381, 15 of which are duplicate entries. Of these there are 80 holotypes, 21 paratypes, 49 cotypes, 179 plesiotypes, 14 chirotypes, 3 plastotypes and 20 figured specimens.

ALPHABETICAL LIST.

16285. *Acanthoclema sulcatum* Hall and Simpson. Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 31, Pl. II, Figs. 13, 14.

16229. *Ambocoelia umbonata* (Conrad). Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 49.

15330. *Ancylopus ortoni* Carman. Holotype.
Monongahela (Penn.). New Straitsville, Ohio.
CARMAN. Bull. Geol. Soc. Amer., Vol. XXXVIII, 1927, pp. 391–395, Pl. XIII.

15329. *Anomoeichnus ohioensis* Carman. Holotype.
Middle Kitanning, Allegheny (Penn.). New Straitsville, Ohio.
CARMAN. Bull. Geol. Soc. Amer., Vol. XXXVIII, 1927, pp. 388–391, Pl. XII.

16281. *Arthracantha carpenteri* (Hinde). Plesiotypes (3).
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 22, Pl. I, Figs. 9–11.

16511. *Atrypa reticularis* (Linnaeus). Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 42, Pl. IV, Fig. 1.

16512. *Athyris vittata* Hall. Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 49, Pl. V, Fig. 1.

16270. *Aulopora serpens* Goldfuss (?). Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 19, Pl. I, Fig. 4.

16553. *Baropus hainesi* Carman. Holotype.

16554. *Baropus hainesi* Carman. Paratype.
Monongahela (Penn.). Hackney, Morgan Co., Ohio.
CARMAN. Bull. Geol. Soc. Amer., Vol. XXXVIII, 1927, pp. 385–388, Pl. XI.

16965. *Bellephon hyaline* Hall. Plesiotype.
Columbus limestone (chert zone) (Dev.). Dublin, Ohio.
STAUFFER. Geol. Surv. Ohio, Fourth Ser., Bull. 10, 1909, pp. 190–191, Pl. XVII, Figs. 3, 4.

16286. *Botryllopora socialis* Nicholson. Plesiotype.
Silica shale (Dev.). Silica, Ohio.
HALL AND SIMPSON. Pal. N. Y., Vol. VI, 1887, p. 282, Pl. LXIV, Fig. 3.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 28, Pl. II, Figs. 5, 6.

16537. *Bythocypris indianensis* Ulrich. Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Ohio Jour. Sci., Vol. XXX, 1930, No. 1, p. 58, Pl. I, Fig. 13.

16513. *Camarotoechia prolifica* Hall (?). Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 41, Pl. III, Fig. 24.

16271. *Ceratopora flabellata* Greene. Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 20, Pl. I, Fig. 5.

16272. *Ceratopora jacksoni* Grabau. Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 20, Pl. I, Fig. 6.

16505. *Chonetes coronatus* (Conrad). Plesiotypes (3).
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 37, Pl. III, Figs. 13–15.

16259. *Chonetes fragilis* Stewart. Cotypes (4).
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, pp. 38–39, Pl. III, Figs. 16–19.

16300. *Craniella hamiltonæ* Hall. Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 35, Pl. III, Fig. 8.

16523. *Crinoid stems.* Figured (4).
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 25, Pl. I, Figs. 12–15.

16507. *Cyrtina hamiltonensis* Hall. Plesiotypes (2).
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 43, Pl. III, Figs. 27, 28.

5887. *Cyrtoceras hertzeri* Hall and Whitfield. Holotype.
Niagaran (Sil.). Cedarville, Greene Co., Ohio.
HALL AND WHITFIELD. Pal. Ohio, Vol. II, 1875, p. 150, Pl. VIII, Figs. 7, 8.
= *Hexameroceras hertzeri.*

16273. *Cystiphyllum vesiculosum* Goldfuss. Plesiotypes (4).
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 18.

16287. *Cystodictya incisurata* (Hall). Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 33, Pl. III, Figs. 5, 6.

16265. *Cytherella (?) bispinulatus* Stewart. Cotypes (3).
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 60, Pl. V, Figs. 18, 19.

16515. *Diaphorostoma lineatum* (Conrad). Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 56, Pl. V, Fig. 11.

3082. *Diestoceras eos* (Hall and Whitfield). Holotype.
Richmond (Ord.). Near Dayton, Ohio.
FOERSTE. Jour. Sci. Lab., Denison Univ., Vol. XX, 1924, p. 265, Pl. III, Fig. 5.
See *Gomphoceras eos.*

16963. *Dipterus eastmani* Stauffer. Holotype.
Columbus limestone (Dev.). Whitehouse, Ohio.
STAUFFER. Geol. Surv. Ohio, Fourth Ser., Bull. 10, 1909, p. 196, Pl. XVII, Figs. 14–17.

1876. *Elrodoceras (?) carmani* Foerste. Holotype.
Niagaran (Sil.). Cedarville, Greene Co., Ohio.
FOERSTE. Jour. Sci. Lab., Denison Univ., Vol. XXIII, 1928, p. 261, Pl. LXXI, Fig. 1.

16531. *Favosites nitella* Winchell. Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Ohio Jour. Sci., Vol. XXX, 1930, No. 1, p. 52, Pl. I, Fig. 1.

16289. *Fistulipora vesiculata* (Hall and Simpson). Plesiotypes (2).
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 28, Pl. II, Figs. 3, 4.

3082. *Gomphoceras eos* Hall and Whitfield. Holotype.
Richmond (Ord.). Near Dayton, Ohio.
HALL AND WHITFIELD. Pal. Ohio, Vol. II, 1875, p. 100, Pl. III, Fig. 5.
= *Diestoceras eos.*

7304. *Graftonoceras graftenense* (Meek and Worthen). Plesiotype.
Niagaran (Sil.). Rising Sun, Ohio.
FOERSTE. Jour. Sci. Lab., Denison Univ., Vol. XXI, 1925, p. 59, Pl. XII, Figs. 3A, B.

3404. *Graftonoceras ortoni* (Meek). Holotype.
Niagaran (Sil.). Greenville, Ohio.
FOERSTE. Jour. Sci. Lab., Denison Univ., Vol. XXI, 1925, p. 61, Pl. XII, Figs. 5A, B.
See *Lituites (?) ortoni* Meek.

7057. *Graftonoceras ortoni* (Meek). Plesiotype.
Niagaran (Sil.). Wilmington, Ohio.
FOERSTE. Jour. Sci. Lab., Denison Univ., Vol. XXI, 1925, p. 61, Pl. XII, Figs. 4A–E.

16522. *Grammysia bisulcata* (Conrad). Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 50, Pl. V, Fig. 2.

16290. *Hederella canadensis* (Nicholson). Plesiotypes (2).
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 25, Pl. I, Figs. 16, 17.

16292. *Hederella cirrhosa* Hall. Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 26, Pl. I, Fig. 18.

16293. *Hederella magna* Hall. Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 26, Pl. I, Fig. 19.

16274. *Heliophyllum halli* Milne-Edwards and Haime. Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 19, Pl. I, Fig. 3.

5887. *Hexameroceras hertzeri* (Hall and Whitfield). Holotype.
Niagaran (Sil.). Cedarville, Greene Co., Ohio.
FOERSTE. Jour. Sci. Lab., Denison Univ., Vol. XXIV, 1929, p. 375, Pl. XLIX, Figs. 3A, B.
See *Cyrtoceras hertzeri.*

16768. *Intrapora (?) irregularis* Stewart. Cotypes (2).
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 33, Pl. III, Figs. 2–4.

16538. *Isochilina scapha* Stewart. Holotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Ohio Jour. Sci., Vol. XXX, 1930, No. 1, p. 57, Pl. I, Figs. 11, 12.

14802. *Kionoceras* sp. Figured.

(3431A). Niagaran (Sil.). Yellow Springs, Ohio.

FOERSTE. Jour. Sci. Lab., Denison Univ., Vol. XXIII, 1928, p. 290, Pl. LXV, Fig. 3.

14803. *Kionoceras* sp. Figured.

(3431B). Niagaran (Sil.). Yellow Springs, Ohio.

FOERSTE. Jour. Sci. Lab., Denison Univ., Vol. XXIII, 1928, p. 290, Pl. LXII, Fig. 6.

3160. *Kionoceras strix* (Hall and Whitfield). Plesiotype.
Niagaran (Sil.). Cedarville, Greene Co., Ohio.

FOERSTE. Jour. Sci. Lab., Denison Univ., Vol. XXIII, 1928, p. 293, Pl. LXVII, Fig. 1.

16533. *Leiorhynchus kelloggi* Hall. Plesiotype.
Silica shale (Dev.). Silica, Ohio.

STEWART. Ohio Jour. Sci., Vol. XXX, 1930, No. 1, p. 54, Pl. I, Figs. 3, 4.

16260. *Leiorhynchus lucasi* Stewart. Holotype.
Silica shale (Dev.). Silica, Ohio.

STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 42, Pl. III, Figs. 25, 26.

16536. *Leperditia (?) subrotunda (?)* Ulrich. Plesiotype.
Silica shale (Dev.). Silica, Ohio.

STEWART. Ohio Jour. Sci., Vol. XXX, 1930, No. 1, p. 57, Pl. I, Fig. 10.

3404. *Lituites (?) ortoni* Meek. Holotype.
Niagaran (Sil.). Greenville, Ohio.

MEEK. Pal. Ohio, Vol. I, 1873, p. 186, Pl. XV, Fig. 4.
(*Gyroceras ortoni* at end of description.)

= *Graftonoceras ortoni.*

16139. *Modiomorpha concentrica* Hall. Plesiotype.
Silica shale (Dev.). Silica, Ohio.

STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 52, Pl. V, Fig. 4.

16514. *Modiomorpha mytiloides* (Conrad) (?). Plesiotype.
Silica shale (Dev.). Silica, Ohio.

STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 53, Pl. V, Fig. 5.

16267. *Monotrypella ohioensis* Stewart. Cotypes (4).
Silica shale (Dev.). Silica, Ohio.

STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, pp. 29–30, Pl. II, Figs. 7–10.

16294. *Monotrypella* sp. Figured.
Silica shale (Dev.). Silica, Ohio.

STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 30, Pl. III, Fig. 1.

16967. *Murchisonia eversolensis* Stauffer. Holotype.
Columbus limestone (chert zone) (Dev.). Eversole Run, Ohio.
STAUFFER. Geol. Surv. Ohio, Fourth Ser., Bull. 10, 1909, p. 191, Pl. XVI, Fig. 13.

16968. *Murchisonia intermedia* Stauffer. Holotype.
Columbus limestone (chert zone) (Dev.). Eversole Run, Ohio.
STAUFFER. Geol. Surv. Ohio, Fourth Ser., Bull. 10, 1909, pp. 191–192, Pl. XVI, Fig. 91.

16969. *Murchisonia quadricarinata* Stauffer. Cotypes (2).
Columbus limestone (chert zone) (Dev.). Eversole Run, Ohio.
STAUFFER. Geol. Surv. Ohio, Fourth Ser., Bull. 10, 1909, p. 192, Pl. XVII, Figs. 10, 11.

3405. *Ophidioceras wilmingtonense* Foerste. Holotype.
Niagaran (Sil.). Yellow Springs, Ohio.
FOERSTE. Jour. Sci. Lab., Denison Univ., Vol. XXI, 1925, p. 66, Pl. XXIV, Figs. 4A, B.

3423A. *Orthoceras crebescens* Hall and Whitfield. Plesiotype.
Niagaran (Sil.). Cedarville, Greene Co., Ohio.
HALL AND WHITFIELD. Pal. Ohio, Vol. II, 1875, p. 148, Pl. IX, Fig. 2.
= *Orthoceras whitfieldi.*

3423A. *Orthoceras whitfieldi* Foerste. Paratype.
Niagaran (Sil.). Cedarville, Greene Co., Ohio.
FOERSTE. Jour. Sci. Lab., Denison Univ., Vol. XXIII, 1928, p. 243, Pl. L, Fig. 2.
See *Orthoceras crebescens.*

17114. *Orthophragmina meroensis* W. Berry. Cotypes (3).
Samon cgl. (Eocene). Cal Mero, Peru.
W. BERRY. Jour. Wash. Acad. Sci., Vol. XX, 1930.

16964. *Palaeoneilo (?) sanduskiensis* Stauffer. Holotype.
Delaware limestone (Dev.). Sandusky, Ohio.
STAUFFER. Geol. Surv. Ohio, Fourth Ser., Bull. 10, 1909, p. 190, Pl. XVI, Figs. 7, 8.

16295. *Paleschara (?)* sp. Figured.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 34, Pl. III, Fig. 7.

16266. *Phacops rana* var. *milleri* Stewart. Cotypes (3).
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, pp. 58–60, Pl. V, Figs. 14–17.

16502. *Pholidostrophia iowaensis* (Owen). Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 36, Pl. III, Fig. 12.

3145.

3148. *Phragmoceras augustum* (Newell). Plesiotypes (3).

3149. Niagaran (Sil.). Marion, Indiana.
FOERSTE. Jour. Sci. Lab., Denison Univ., Vol. XXIV, 1929, p. 330.

7302A. *Phragmoceras auroraense* Foerste. Holotype.

7302B. *Phragmoceras auroraense* Foerste. Paratype.
Niagaran (Sil.). Rising Sun, Ohio.
FOERSTE. Jour. Sci. Lab., Denison Univ., Vol. XXIV, 1929, p. 333, Pl. LIII, Figs. 1A, B; 2A, B.

14809B. *Phragmoceras auroraense* Foerste. Paratype.

(9442B). Niagaran (Sil.). Bowling Green, Ohio.
FOERSTE. Jour. Sci. Lab., Denison Univ., Vol. XXIV, 1929, p. 333, Pl. LIII, Fig. 3.

14912. *Phragmoceras carmani* Foerste. Holotype.
Niagaran (Sil.). Greene Co., Ohio.
FOERSTE. Jour. Sci. Lab., Denison Univ., Vol. XXIV. 1929, p. 337, Pl. LV, Fig. 1.

9442A. *Phragmoceras* cf. *colliciare* Foerste. Paratype.
Niagaran (Sil.). Bowling Green, Ohio.
FOERSTE. Jour. Sci. Lab., Denison Univ., Vol. XXIV, 1929, p. 339, Pl. LII, Figs. 3A, B.

3413. *Phragmoceras ellipticum* Hall and Whitfield. Holotype.
Niagaran (Sil.). Highland Co., Ohio.
HALL AND WHITFIELD. Pal. Ohio, Vol. II, 1875, p. 152, Pl. 8, Fig. 11.
FOERSTE. Jour. Sci. Lab., Denison Univ., Vol. XXIV, 1929, p. 343, Pl. L, Fig. 4.

3414. *Phragmoceras hillsborense* Foerste. Holotype.
Niagaran (Sil.). Highland Co., Ohio.
FOERSTE. Jour. Sci. Lab., Denison Univ., Vol. XXIV, 1929, p. 345, Pl. LI, Figs. 1A, B.

5889. *Phragmoceras parvum* Hall and Whitfield. Holotype.
Niagaran (Sil.). Cedarville, Ohio.
HALL AND WHITFIELD. Pal. Ohio, Vol. II, 1875, p. 151, Pl. VIII, Fig. 10.
FOERSTE. Jour. Sci. Lab., Denison Univ., Vol. XXIV, 1929, p. 351, Pl. LV, Fig. 2.

9441A. *Phragmoceras wilmingtonense* Foerste. Paratype.
Niagaran (Sil.). Bowling Green, Ohio.
FOERSTE. Jour. Sci. Lab., Denison Univ., Vol. XXIV, 1929, p. 359, Pl. LI, Figs. 2A, B.

16974. *Platyceras blatcheyi* Kindle. Plesiotype.
Columbus limestone (zone H) (Dev.). Dublin, Ohio.
STAUFFER. Geol. Surv. Ohio, Fourth Ser., Bull. 10, 1909, p. 192, Pl. XVI, Figs. 11, 12.

16144. *Platyceras bucculentum* Hall. Plesiotypes (2).
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 54, Pl. V, Figs. 6, 7.

16516. *Platyceras carinatum* Hall. Plesiotypes (2).
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 55, Pl. V, Figs. 8, 9.

16517. *Platyceras rarispinum* Hall. Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 56, Pl. V, Fig. 10.

16973. *Platyostoma subglobosa* Stauffer. Holotype.
Columbus limestone (chert zone) (Dev.). Eversole Run, Ohio.
STAUFFER. Geol. Surv. Ohio, Fourth Ser., Bull. 10, 1909, p. 192, Pl. XVI, Fig. 6.

16970. *Pleurotomaria cancellata* Stauffer. Cotypes (2).
Columbus limestone (chert zone) (Dev.). Eversole Run, Ohio.
STAUFFER. Geol. Surv. Ohio, Fourth Ser., Bull. 10, 1909, p. 193, Pl. XVII, Figs. 1, 2.

16971. *Pleurotomaria dublinensis* Stauffer. Cotypes (3).
Columbus limestone (chert zone) (Dev.). Dublin, Ohio.
STAUFFER. Geol. Surv. Ohio, Fourth Ser., Bull. 10, 1909, p. 193, Pl. XVII, Figs. 7–9.

16972. *Pleurotomaria sciotensis* Stauffer. Cotypes (2).
Columbus limestone (chert zone) (Dev.). Eversole Run, Ohio.
STAUFFER. Geol. Surv. Ohio, Fourth Ser., Bull. 10, 1909, p. 194, Pl. XVII, Figs. 5, 6.

16544. *Productella spinulicosta* Hall. Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 39.

16976. *Proetus welleri* Stauffer. Holotype.
Columbus limestone (Dev.). South of Venice, Ohio.
STAUFFER. Geol. Surv. Ohio, Fourth Ser., Bull. 10, 1909, p. 195, Pl. XVII, Figs. 12, 13.

16140. *Pterinea flabellum* Conrad. Plesiotypes (4).
Silica shale (Dev.). Silica, Ohio.
HALL. Pal. N. Y. Vol., V, Pt. I, Lamellibranchiata, 1884, p. 93, Pl. XIV, Fig. 3.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 51, Pl. V, Fig. 3.

16296. *Reptaria stolonifera* Rolle. Plesiotypes (2).
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 27, Pl. II, Figs. 1, 2.

16297. *Reteporina striata* Hall. Plesiotypes (2).
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 30, Pl. II, Figs. 11, 12.

16503. *Rhipidomella vanuxemi* Hall. Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 40, Pl. III, Fig. 20.

16501. *Schizophoria striatula* (Schlotheim). Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 40, Pl. III, Fig. 21.

16261. *Schizophoria striatula* v. *parvum* Stewart. Holotype and Paratype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 40, Pl. III, Figs. 22, 23.

16510. *Spirifer audaculus* (Conrad). Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 44, Pl. IV, Figs. 2, 3.

16263. *Spirifer bownockeri* Stewart. Cotypes (3).
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, pp. 45–46, Pl. IV, Figs. 4–6.

16508. *Spirifer euryteines* Owen. Plesiotypes (2).
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 46, Pl. IV, Figs. 7, 8.

16961. *Spirifer lucasensis* Stauffer. Cotypes (5).
Traverse formation (Dev.). Whitehouse, Ohio.
STAUFFER. Geol. Surv. Ohio, Fourth Ser., Bull. 10, 1909, pp. 188-189, Pl. XVI, Figs. 1–5.

16262. *Spirifer mucronatus* v. *prolificum* Stewart. Cotypes (6).
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, pp. 47–49, Pl. IV, Figs. 9–14.

16280. *Spirorbis arkonensis* Nicholson. Plesiotype.
Stropheodonta perplana (Conrad). Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 21, Pl. III, Fig. 11.

16264. *Spirorbis planum* Stewart. Holotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, pp. 21–22, Pl. I, Figs. 7, 8.

16269. *Stictoporina granulifera* Stewart. Holotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 32, Pl. II, Figs. 17–19.

16975. *Straparollus corrugatus* Stauffer. Holotype.
Columbus limestone (chert zone) (Dev.). Eversole Run, Ohio.
STAUFFER. Geol. Surv. Ohio, Fourth Ser., Bull. 10, 1909, p. 194, Pl. XVI, Fig. 10.

16298. *Streblotrypa hamiltonensis* Nicholson. Plesiotypes (2).
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 31, Pl. II, Figs. 15, 16.

16299. *Stropheodonta demissa* (Conrad). Plesiotypes (2).
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 35, Pl. III, Figs. 9, 10.

16532. *Stropheodonta demissa* var. Figured.
Silica shale (Dev.). Silica, Ohio.
STEWART. Ohio Jour. Sci., Vol. XXX, 1930, No. 1, p. 53, Pl. I, Fig. 2.

16280. *Stropheodonta perplana* (Conrad). Plesiotype.
Spirorbis arkonensis Nicholson. Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 36, Pl. III. Fig. 11.

16519. *Styliolina fissurella* (Hall). Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 57, Pl. V, Fig. 12.

16520. *Tentaculites bellulus* Hall (?). Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 57, Pl. V, Fig. 13.

16534. *Terebratula mediocris* Stewart. Holotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Ohio Jour. Sci., Vol. XXX, 1930, No. 1, p. 55, Pl. I, Figs. 5–7.

16535. *Tornoceras uniangularis* (Conrad). Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Ohio Jour. Sci., Vol. XXX, 1930, No. 1, p. 56, Pl. I, Figs. 8, 9.

17109. *Xiphias (?) drydeni* W. Berry. Holotype.
Calvert (?) (Miocene). Calvert Co., Maryland.
W. BERRY. Jour. Wash. Acad. Sci., Vol. XX, No. 3, Feb. 1930, p. 41, Figs. 1, 2.

16278. *Zaphrentis prolifica* Billings. Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, pp. 16–17, Pl. I, Fig. 1.

16277. *Zaphrentis simplex* Hall. Plesiotype.
Silica shale (Dev.). Silica, Ohio.
STEWART. Geol. Surv. Ohio, Fourth Ser., Bull. 32, 1927, p. 17, Pl. I, Fig. 1.

THIRD LAYER OF AMOEBA VS. TRICHOCYSTS OF PARAMECIUM.*

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INTRODUCTION.

We are often asked by students and co-workers why amoebæ with no weapons of defense can capture and digest *Paramecium caudatum* and other protozoa when these organisms possess such weapons as trichocysts (Fig. 3).

We believe we can answer the above question from observations we have made. In these observations, which will be described in detail in the following pages, we have found that, when an Amoeba has succeeded in killing a Paramecium, the former organism was mature in practically every case. An immature amoeba was unsuccessful according to our observations, since the third layer was not thick enough to protect it from the trichocysts of the Paramecium. We feel the third layer is the essential structure used by the Amoeba in securing food and, therefore, we have described the characteristics of that layer in the following paragraphs.

THE THIRD LAYER.

That a third layer exists on an Amoeba was indicated by observations made by Butschli (2) in 1892 and by Blochmann (1) in 1894. Several years later Gruber (4) recognized the same structure and described it as a permanently differentiated layer composed of gelatinous substance. Schaeffer (12) in 1917 called the third layer one of protoplasm which moves faster than the forward advance of the Amoeba and later gave a very clear description of its movements as indicated by its ability to carry particles.

Jennings, (5) on the other hand, concluded from his observations that no third layer existed, but that particles clinging to the outside of the Amoeba were carried toward the anterior end by the ectoplasm.

*We are indebted to Doctor H. O. Halvorson for many helpful criticisms in preparing this paper.

We are convinced, however, that a third layer does exist and that the age of the Amoeba determines the thickness of this layer. We are further convinced that the thickness of the third layer is an important factor in determining the kind of food secured by the Amoeba. In this connection, we noticed in our cultures that a very young Amoeba lives upon bacteria,

FIG. 1. Amoeba with its third layer surrounding a Chilomonas paramecium.

FIG. 2. Chilomonas paramecia with the third layer of an amoeba surrounding them forming food vacuoles.

FIG. 3. The third layer of an amoeba surrounding two Chilomonas paramecia at the extreme right. The third layer disappears as the food vacuoles approach the nucleus. At the posterior end of the amoeba there are numerous Chilomonas paramecia. These were caught when the amoeba was flowing in the direction opposite to the one shown in the diagram.

when older it chooses *Chilmonas paramecium* (Text Figs. 1, 2, 3), later paramecia is the principal diet, and finally Rotifers are selected.

According to our observations practically all conflicts between mature Amoeba and Paramecium were fought to the advantage of the former organism. On the other hand a young Amoeba, in such a battle, always lost. While working on the life cycle of *Amoeba proteus*, (Jones (6), we observed in

one of Dr. Kepner's cultures a conflict between a young Amoeba, a Paramecium and another protozoan, *Urotricha farcata*. In this skirmish, the Amoeba attacking the Paramecium, began to project pseudopodia almost immediately on either side of the Paramecium but before they had extended far, it put out another in the opposite direction as if to move away. In the meantime, *U. farcata* came up to the Paramecium and stopped, then it tried to move away but its efforts were feeble. The Paramecium by means of its trichocysts killed both the Amoeba and *U. farcata*. At this point the Paramecium was killed with osmic acid fumes and fixed as described below.* In the photograph (Fig. 1), the reader can see the trichocysts discharged into the Amoeba and *Urotricha* and that the latter is a little swollen in the direction of the Paramecium. It is of interest to note the Paramecium apparently discharged only those trichocysts which came in contact with the Amoeba and *Urotricha*.

Although, as previously stated, we feel that the age of the Amoeba and, therefore, the amount of third layer present is extremely important in determining the kind and size of food secured by the organisms, we have also noticed that even a mature Amoeba is not always successful in killing a Paramecium. Sometimes the latter is able to free itself without difficulty from an Amoeba. Such an escape, we are confident is due to the absence of a necessary amount of third layer on the surface of the Amoeba at the time the Paramecium is caught. When the Amoeba has caught several organisms, each of those animals takes with it to the interior of the Amoeba a certain amount of third layer, (Text Figs. 2, 3). As a result, if several organisms have previously been caught and, therefore, several food cups formed in the Amoeba, there naturally will be less of the third layer on the surface. Under such a condition the Amoeba is of course less able to hold its prey, and often the latter gets away. Kepner and Whitlock (10) show a good example of this in Plate III (Fig. 12). In this illustration it is evident that an Amoeba caught a euglena after several other organisms has previously been secured. The euglena escaped, a condition due, undoubtedly, to an insufficient amount of third layer on the surface of the Amoeba at the time the flagellate was caught.

*The organisms were killed with osmic acid fumes, fixed in Schaudinn solution (Saturated $HgCl_2$ in 95 per cent alcohol plus acetic acid) and stained in Heidenhain's iron-alum-haematoxylin (short method).

The small amount of third layer present on the surface was needed by the Amoeba to protect the ectoplasm and endoplasm of its body from the lashing flagellum of the euglena.

There are no indications of the third layer possessing any power of digestion, since no signs of erosion occur until all the third layer has left the food vacuoles or has been digested by the enzymes in the endoplasm.

After protozoa have been caught and taken into the Amoeba, the food vacuole containing the imprisoned organisms passes towards the nucleus. During this passage the third layer, taken in the food vacuole with the organisms, gradually disappears and is entirely gone by the time the vacuole reaches the nucleus (Text Figs. 3). The contents of the food vacuole are then digested and the indigestible particles pass away from the nucleus and out of the Amoeba at the posterior end.

When an Amoeba catches protozoa at one end and then reverses its direction of flow, such as illustrated in Text figure 3, the organisms caught remain at the posterior end until the movements of the Amoeba cease or are reversed again.

TRICHOCYSTS.

Paramecium in defending themselves against Amoeba, project short stout rods called trichocysts. Although there is little definite information about these rods it is known that they lie within the ectoplasm. A few investigators are of the opinion that trichocysts are used chiefly for protection, others feel they must be weapons used for offense while still others hesitate to credit them with either function. Mast (11) supporting the theory that the Paramecium uses its trichocysts for protection, discusses the behavior of the organism when encountering its worst enemy, the *Didinium*. The latter attacks its prey by means of a peristome which can be discharged as an elongated tubler proboscis. If it succeeds in fixing this structure to a Paramecium it is usually able to suck much of its prisoner's body into its own. According to Mast (11), when the Paramecium is attacked by a *Didinium*, it discharges its trichocysts, which form a great tangled mass about the body of its enemy. This discharge of trichocysts, in the cases of the largest Paramecia forms such a dense mass that the *Didinium* is pushed free from the Paramecium and the latter thus escapes death.

Our observations coincide with those of Mast, but we have also noticed that the trichocysts are entirely liberated from the body of the Paramecium when it is attacked by a *Didinium* but are not liberated when it is attacked by other animals. Such a condition, we feel, must be due to a stimulus caused by an injection of material from the proboscis of the *Didinium*. Figures 1, 3, shows trichocysts discharged but still attached to the Paramecium.

A MATURE AMOEBA ENGULFS A PARAMECIUM WITH ITS THIRD LAYER.

When a Paramecium is not moving about but has its cilia in motion, currents are set up by the cilia which become swifter as they pass from the anterior to the posterior end of the animal. If an Amoeba is near enough the Paramecium to receive a stimulus from these currents, the first pseudopodium formed by the Amoeba will be pointed toward the posterior end of the Paramecium, since this is the source of greatest stimulus. As the Amoeba moves nearer the Paramecium, other pseudopodia of smaller size are formed. These are right and left of the first pseudopodium. When a pseudopodium touches the Paramecium the third layer of that pseudopodium immediately engulfs the Paramecium.

In catching a Paramecium or any other animal of similar structure, it is necessary for the third layer of the Amoeba to first surround or engulf the emprisoned organism. Naturally according to this method of securing food, it is necessary for the Amoeba to have plenty of third layer.

Kepner and Whitlock's (10) drawings, reproduced on Plate III (Figs. 9, 10, 11), describe the catching of a Paramecium by an Amoeba as follows: The amoeba was advancing in a general way toward the Paramecium along pseudopodia 1, 2 and 3. As it approached the ciliate, pseudopodia 1 and 2 widened and partly fused to form a large bi-lobed extremity, m-ml. When this extremity had nearly touched the Paramecium, it sent out a small psudopodium, beneath the prey, and b anterior to it (Fig. 10). When the pseudopodia, a and b came in contact with the detritus, y, they moved apart and become much stouter (Fig. 11). In the meantime a third pseudopodium, e, appeared projecting from between a and b over the dorsal side of the Paramecium, while a pocket was formed within the body

proper of the amoeba at the bases of these three pseudopodia. The Paramecium first jumped to position 2, Fig. 11. The excited Paramecium next backed into the pocket of the body proper, 3 and a, b, and e, closed in and surrounded it completely."

Our interpretations of the diagrams described above differ from those given by Kepner and Whitlock, since we bring into use the third layer. According to our interpretations the Paramecium was still, but its cilia were moving violently, judging by the amount of debris that was passing along the side and back of the posterior end of the Paramecium. The stimulus thus set up caused the Amoeba to put forth pseudopodium number 2 first, 3 next, then one, since this was the order of the stimulus as it was received by the Amoeba; notice, number 1 would touch the Paramecium about the center; 2 is off at the posterior end, while 3 would be useless in catching the Paramecium. The next in order, number 4, would be out of consideration. As 1 and 2 approached nearer the Paramecium, the third layer of either pseudopodia 1 and 2 or both would flow around and engulf the Paramecium. Figure 4, text figures 1 and 2, shows the third layer of an Amoeba surrounding *Chilomonas paramecium* in this same fashion.

The engulfing of a paramecium by the third layer may be due to the adhesive forces. The third layer having a strong affinity for the surface of a paramecium tends to flow over and around it. This same flow may cause a shifting of surface tension forces, which will account in part, at least, for the withdrawal of extended pseudopodia as in Plate III, Fig. 10. Part of the third layer having flowed around the Paramecium will tend to level out, due to surface tension forces, thus drawing the Paramecium into the cytoplasm of the Amoeba or, visa versa, the cytoplasm of Amoeba around the Paramecium. As a result, secondary pseudopodia flow up through the third layer and around the paramecium finally engulfing the organism along with some of the third layer as pictured by Kepner and Whitlock (10), Plate III, Fig. 11. These authors, in observing this condition, however, pictures the Amoeba surrounded by a layer of water instead of protoplasmic substance. According to our observations, third layer and not water surrounded the engulfed organism as we were able to stain the material, (Fig. 4, Text figures 1, 2, 3).

Kepner and Whitlock (10) state "that an Amoeba may react to a quiet paramecium in three ways; (1) by forming a pocket within its own body within which the ciliate will be driven (Figs. 9, 10, 11, 12), by sending encircling pseudopodia about the prey and then roofing over and flooring the enclosed space with ectoplasm before disturbing the prey, and (3) by closing in upon the Paramecium with the advancing tips of two pseudopodia until the prey is held fast in a grip of the pseudopodia ends. After the Paramecium is thus caught, it is very tightly closed in upon and constricted."

We have observed that the pseudopodia will only extend around the third layer. In other words, the pseudopodia will not encircle a living protozoan until the third layer has completely surrounded the prey.

We have also seen mature Amoeba catch *Chilomonas paramecium* in the manner described by Kepner and Whitlock (10) but in every instance observed in stained preparations, the third layer had surrounded the *Chilomonas paramecium* before the cup of the Amoeba began to close.

SUMMARY.

1. Paramecium can kill young amoeba with its trichocysts.

2. Mature amoeba has a thicker third layer than an immature one which protects the ectoplasm and endoplasm from the trichocysts of other protozoa.

3. Trichocysts are not thrown off from a paramecium when attacking amoeba and Urotrichia as described by Mast when *Didinium* attacks the paramecium.

4. Pseudopodia will not extend around an organism until the third layer has first surrounded it.

5. The organism caught by an amoeba is carried towards the nucleus, the third layer in the food vacuole disappears as digestion takes place.

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EXPLANATION OF PLATES.

Plate I.

Fig. 1. Paramecium with its trichocysts discharged, killing a young amoeba and a Urotricha.

Fig. 2. *Amoeba proteus* showing the third layer surrounding the amoeba. The amoeba is filled with food vacuoles. Notice the two Chilomonas paramecia. The one at the posterior end shows signs of erosion, while the one at the large end shows no such change. The dark bodies, except the large one which is the nucleus, are food vacuoles in different degrees of digestion.

Fig. 3. Paramecium cordatum with its trichocysts extended; the capsules are stained black with iron heamatoxylin.

Plate II.

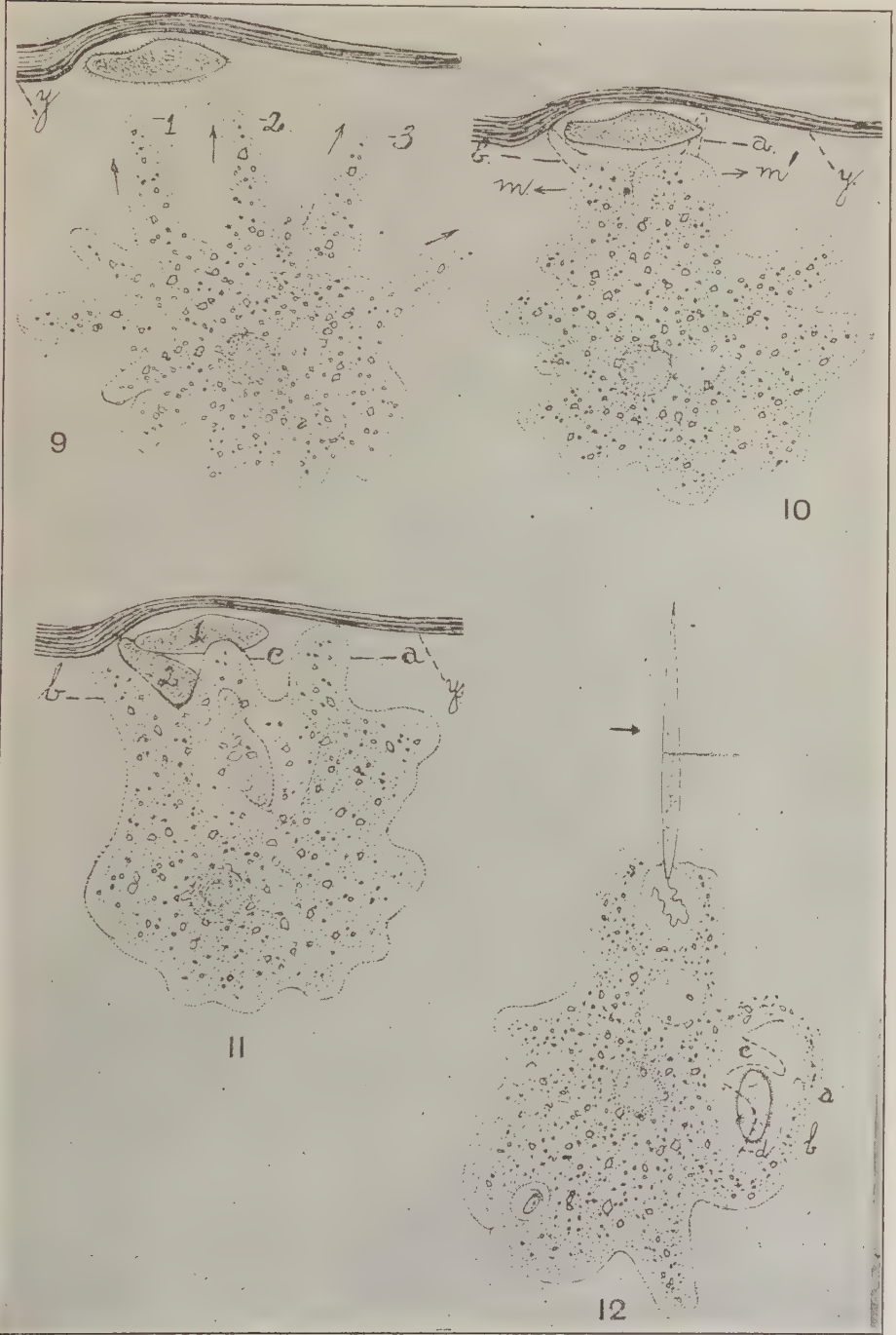
Fig. 4. Amoeba catching active moving Chilomonas paramecia by surrounding them with the third layer on the arms while it is catching a chilomonas in a food cup at the larger end.

Plate III.

Figs. 9, 10 and 11. Shows an amoeba catching a paramecium as explained by Kepner and Whitlock. (Reproduced by permission of Dr. Kepner.)

1
2

4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PLASMODIOPHORA LEWISII, NOV. SP.

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In the spring of 1926, I found mycetozoa living on some tomato and tobacco plants in the University of Chicago greenhouse. I picked up some of these organisms with a Barber pipette and transferred them to six 500 c.c. flasks containing 100 c.c. of serile Knop's solution. Bacteria were put in the flasks for the mycetozoa for food. Knop's solution was used for the organisms instead of wheat or hay infusion because th ph. in the former remains more constant.

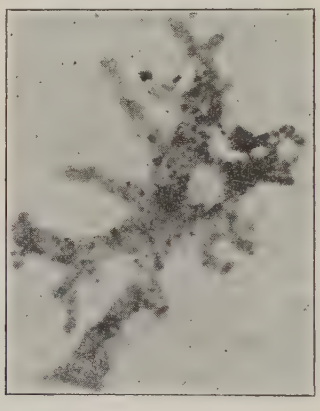

FIG. 1. Preplasmodium of *P. brassicæ* showing its nucleus and the karyosome lying against the nuclear membrane. The black dots filling the cytoplasm are oil globules. ×1000.

When first studying the mycetozoan, I noticed that it had but a single nucleus, which divided by promitosis, (Figs. 2, 3, 11). I also noticed that it moved by a rhythmic flow, which was quite different from the method employed by other mycetozoans. Though this method of movement resembled more that used by the myxomycetes, yet the contents did not flow through the vein-like structure which is so evident in the latter. Since the pseudopodia in this new organism were of typical myxopodia type, (Figs. 2, 3) the organism may be assumed to feed as others with pseudopodia of this kind.

In moving, one pseudopodium would contract with a rapid flowing movement into a lobe-like structure, (Figs. 2, 3). The contents of this lobe would then flow into another pseudopodium as if the lobe had been squeezed. The contraction of the pseudopodium into a lobe followed by the apparent squeezing of this lobe, which caused the contents to go elsewhere, gave the organism the rhythmic movement. The plasmodium in its extended form averaged 76 u. in length.

This new mycetozoan reminded me very much of the pre-plasmodium I have reported for *Plasmodiophora brassicæ*, (b) (Text Fig. 1). Oil globules, however, which were found in the latter, were missing in this organism. The method of movement also was very different from that found in *P. brassicæ*.

PRE-CYST.

In unfavorable conditions the whole plasmodium would round itself into a ball (Fig. 1). A thin wall was first secreted about the organism (pre-cyst) and then if conditions were again favorable, the plasmodium would flow out of the pre-cystic condition leaving the pre-cyst wall behind and move and feed as before, (Fig. 8). The pre-cyst averaged 20 u. in diameter. If, however, favorable conditions did not return after the pre-cyst was formed, another wall, much thicker than the first would be formed and a true cyst was the result, (Fig. 6). The cyst averaged 14 u. in diameter.

NUCLEUS.

The nucleus was a spherical structure, and appeared very small for the amount of cytoplasm. It had a karyosome which did not lie in the center of the nucleus but to one side, touching the nuclear membrane, (Fig. 10). During nuclear division this karyosome divided first, which the spindle occurring between the two polar masses, within the nuclear membrane, (Fig. 11). The organism then divided forming two new individuals, I have often found the plasmodium with two nuclei before the cytoplasm divided. Only twice have I found a plasmodium with four nuclei.

AMOEBA AND FLAGELLATE STAGES.

When favorable conditions such as food and temperature returned, the nucleus of the plasmodia cyst gave off chromidia

into the cytoplasm. Small flagellates were developed from these chromidia. The cyst and pre-cyst walls soon ruptured (Fig. 4), and the flagellates were liberated, (Fig. 5). These flagellates had a single flagellum, but showed no signs of conjugation. After swimming around in a dancing movement for a time these organisms developed pseudopodia at the posterior end. The pseudopodia were used in obtaining bacteria for food.

The flagellates later changed into amoebæ (Fig. 7). This change occurred under certain conditions as described in *P. tabaci* (a). In the amoeba stage the ectosarc could not be differentiated from the endosarc although the food material inside the organism might at first sight give one the impression that the two layers could be distinguished. I also noticed that the two cell layers could not be differentiated in the plasmodium stage.

If unfavorable conditions arose during the amoeba stage, the organism developed into a pre-cyst and cyst. Under normal conditions, however, the amoeba continued in this stage until a certain period of growth was reached and then was transformed into a pre-cyst. During this pre-cyst stage the nucleus gave off chromidia (Fig. 4), as was done in the cyst stage. I have not observed any gametes formed from these chromidia but judging from such an occurrence in *P. brassicæ* (b), *P. tabaci* (a), and *Amoeba proteus* (c), I firmly believe that gametes are produced following the pre-cyst stage in this organism. I also believe that the sexual stage takes place following the pre-cyst condition before the plasmodium is produced.

CLASSIFICATION.

Sub-phylum—Sarcondia, Calkins.
Class—Rhizopoda, Calkins.
Sub-class—Mycetozoa, Debary.
Order—Phytomyxidia, Schroter.
Family—Plasmodiophoraceæ, Gaumann.
Genus—Plasmodiophora, Woronin.
Species—Lewisii.*

*Named for Doctor I. F. Lewis, of the University of Virginia.

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EXPLANATION OF PLATE I.

(All photographs are ×960.)

Fig. 1. Pre-cyst just before the wall is formed.

Figs. 2, 3. Two plasmodia which have just formed lobes. Each lobe was formed by a contraction of a single pseudopodium.

Fig. 4. Pre-cyst of mature amoeba. The nucleus is giving off chromidia.

Fig. 5. Flagellate Stage.

Fig. 6. Cyst of a plasmodium.

Fig. 7. Amoeba which was formed from a flagellate.

Fig. 8. Plasmodium flowing out of a pre-cyst.

Fig. 9. Pre-cyst of young amoeba.

Fig. 10. Plasmodium in extended form. The karyosome lying against the nuclear membrane.

Fig. 11. Nucleus of the plasmodium undergoing division by promitosis.

Plasmodiophora Lewisii
Philip M. Jones

PLATE I.